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Science and technology for development:

**main comparative
report of
the STPI project**



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Science and Technology for Development:

Main Comparative Report of the Science and Technology Policy Instruments Project

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Preface

Governments in all countries struggle with the problem of how to ensure that science and technology contribute effectively to solving national problems. In developing countries, the problem is particularly pressing because local scientific and technological skills are usually limited. In the 1960s and early 1970s, policy research, mainly carried out in Latin America and India, demonstrated that the lack of local skills combined with heavy dependence on foreign technology had sometimes led to undesirable patterns of industrialization. The findings spotlighted two basic questions: What can developing country governments do to ensure that their technology and industrialization policies are consistent with national development objectives? And what ways and means are available for implementing policies? The Science and Technology Policy Instruments project (STPI) was designed to answer these questions.

This report consists of a summary of the research that was carried out by the 10 developing country teams who participated in the STPI project. Although the teams were provided with methods guidelines, they were encouraged to develop the project in their own way. The result was rich and varied but difficult to compress into a single synthesis or summary. Francisco Sagasti, the field coordinator of the project, has completed a difficult task well. He has brought out the variety of the results and national experiences, and, where appropriate, has drawn comparisons and conclusions.

Although the project has not fully answered the original questions, it has certainly demonstrated the complexity of the problems. It has shown that government decisions on economic topics have a direct bearing on technological activities and, in fact, are often the *prime* determinants of technology policy. It has identified many policy instruments, and has touched on the efficacy of specific policy instruments. This is a reflection of the complexity of the problem.

The results provide a wealth of information and guidelines to policymakers, much of which has already had an impact in the countries where the research was carried out. In the expectation that the results will also be of interest to a wider audience of policymakers and researchers in many countries, the IDRC is publishing several reports from the STPI project.

C.H.G. Oldham
Associate Director,
Science and Technology Policy Program.

Introduction

This report presents the main results of the Science and Technology Policy Instruments (STPI) research project, a 3½-year study undertaken in 10 less-developed countries and sponsored by the International Development Research Centre, the Department of Scientific Affairs of the Organization of American States, national government agencies, and academic institutions.

During the project, more than 200 reports were prepared by the country teams, consultants to the project, the field coordinator and his staff. The present report summarizes the main findings, examining them and deriving some implications for further research. It aims at provoking thought and reflection and providing tools for more intensive investigations and for policy guidance.

The report comprises three parts, each reflecting its intended audience. The first is a review of the main issues identified and examined in the STPI project and is directed to high-level policymakers. The second, which was reviewed and approved by the STPI editorial committee in Ottawa in April 1978, consists of five chapters summarizing the main features of the STPI project and presenting the key research results. It is directed to government officials, who have responsibilities in science and technology policy, and to researchers, who may be interested in a comparative analysis. It is based on the country reports, reviewed and processed by the field coordinator, his staff, and consultants. The third part consists of 12 self-contained modules that comprise extracts from the country reports and the results of the work carried out under the supervision of the field coordinator's office. It is an overview of the topics covered in the research and is directed to researchers and to government officials, who may be interested in particulars of policy design and implementation. All three parts represent, as accurately as possible, the material in the country reports. The first two parts are contained in this volume; the third is yet to be published.

In the first two parts, which are directed mainly to policymakers and researchers, the references to other works have been kept to a minimum, although some of the ideas and points of view have been advanced elsewhere in the literature.

The report is complemented by a series of technical studies covering specifics, such as science and technology planning, state enterprises and technology policy, consulting and engineering design capabilities, and registries of licencing agreements. The technical studies also include reports solicited from consultants or prepared by the field coordinator's staff, such as a report on technology policy and industrialization in the People's Republic of China, a study on technological dependence/self-reliance, and a review of technology transfer problems and policies.

Colleagues and friends who were involved with the STPI project are too numerous to mention here. The project would not have been possible

without the dedication and efforts of the coordinators who were responsible for the research, the members of the country teams, and the advisers. The country coordinators and the institutions who participated are listed in an appendix of the report. Here, I would like to mention those who contributed substantially to defining the structure of this report: Alejandro Nadal, Jose Tavares, Eduardo Amadeo, KunMo Chung, Fernando Chaparro, and Fernando Gonzalez Vigil.

Onelia Cardettini and Carlos Contreras from the field coordinator's office helped prepare the report, receiving support and advice from Alberto Araoz, Sergio Barrio, Francisco Sercovich, Mirko Lauer, and Anthony Tillet.

Secretarial help and assistance was provided at different times during the preparation of the report by Fina Urquiaga, Nora Manyari, Mylenka Miloslavich, Andriana Barella, Cecilia Otero, Joan Redfern, Yolanda de Castellanos. The administrative support provided by Cecilia de Mendoza and the staff of the Latin American Regional Office of the International Development Research Centre is gratefully acknowledged.

Also, the STPI project owes much to Geoffrey Oldham of the International Development Research Centre and Ruth Zagorin who was formerly director of IDRC's social sciences division for their constant encouragement and support and to Maximo Halty, formerly of the Organization of American States, Alejandro Moya, and Phactuel Rego of the same institution. To all of them I am grateful; they have helped provide a most exciting learning experience.

Francisco R. Sagasti

PART 1

An Overview

Recently, technological considerations were reintroduced into economic theory, which had neglected them for most of the second-third of the present century. A new interest in science and technology policy emerged, highlighted by the contest between East and West for technological leadership in defence. People began to recognize that, during the last 150 years, science-based technology has nurtured Western industry and that the differences in dynamism between European and American industries have been based on advances in technology. In developed countries, the market economies have competed on the basis of technological achievements in industries, and the planned economies have pursued technology as a means of improving the use of productive resources.

The less-developed countries are now acquiring, on the one hand, an artisan, technical, and engineering base (often through the evolution of traditional technologies) and, on the other, the capacity to compete in modern science. This is a stage in which most of the industrialized countries found themselves in the second-half of the 19th and the first 2 decades of the 20th century. Thus, there is an inherent lag in science-related industries in the less-developed world, for the industrialized countries have now entered fully into the stage of systematic, organized, and mass production of new technologies based on scientific findings. Not only is the process accelerating at a rapid pace in the industrialized world but also the continuous transfer of the technologies, which result from these activities, is stunting the development of an endogenous scientific and technological base for industry in the Third World countries.

From the initial manifestations of concern, many policy recommendations emerged. Practically all of them were concepts of science and technology “systems” based on those found in the industrialized nations. “Missing” institutions were identified, policies were suggested, and planning efforts were started, usually neglecting differences in the specific contexts of underdevelopment, employing abstract models as guides to policy formulation and heeding only the supply of scientific and technological knowledge. The common thread running through the recommendations was a naive and widely shared belief that governments could and would intervene promptly and effectively to develop an indigenous scientific and technological base, producing technology

relevant to the needs of industry, and that industry would adopt new technology as soon as it became available. Thus, general S&T policy recommendations were designed and superimposed on relatively unknown scientific, technologic, and industrial structures.

The shortcomings soon became evident. Even in cases where policies and government measures were successful in creating an infrastructure for science and technology, the link with industrial production was nowhere to be seen. Faced with a lack of demand for their services, research institutes, universities, and supporting organizations developed a logic of their own, paid lip service to the “relevant” character of their activities, and demanded an ever-increasing share of government allocations to finance their expansion.

The result was a negative reaction that was given strong support by newly available empirical studies showing the abuses of technology suppliers from the industrialized world, the transnational corporations in particular. There emerged a movement that blamed the lack of demand for local science and technology — the hiatus between the scientific technological structure and production — on the indiscriminate imports of foreign technology. Thus, measures to regulate imports were proposed, and a few institutions to control abuses were created, reducing, or at least modifying, the most visible abuses.

The new movement, like the old, assumed implicitly that the state apparatus represented the interests of nationalistic groups oriented toward self-reliant development.

The scant improvements observed after more than a decade show the limitations and inadequacies of earlier approaches. With very few exceptions, which are found in a handful of countries and in particular sectors, the situation has not altered significantly: science-related technologies generated in the less-developed countries are in no way close to accounting for even a modest share of the technology used in industrial production. The early 1970s focused on the need to understand more completely the nature of S&T policy formulation and implementation processes and to relate them specifically to underdevelopment and to the characteristics of different industrial branches.

Two years of exploratory thinking and consultations with researchers and policymakers led to the organization of the STPI project in mid-1973. The idea was to generate knowledge of the complex interrelations between science, technology, and industry in the context of underdevelopment, supporting policymaking through improved information. Now that the project has been completed, it is clear that the initial categories and concepts were not free from biases. However, the structure of the project, the scale of the intellectual effort, and the diversity of points of view that were incorporated helped to overcome design limitations and to turn the STPI project into a collective learning exercise.

Learning through STPI

The STPI project was a recognition that too much effort had been spent on abstract S&T policy formulation, that positive results had been scant, and that too little work had been done to assess policy impact. Also, it was a sign of the dissatisfaction with the way in which economic development theory treated technological issues. When the STPI project began, the

dissatisfaction was not clearly articulated, but as the project advanced and the lack of theoretical concepts with explanatory power became apparent, the participants in the STPI research network implicitly reached a consensus: empirical data focusing on specific industrial contexts, on the nature of technical change, and on state intervention were absolutely necessary before theorizing could provide satisfactory explanations.

The STPI project was organized as an action-oriented, collective learning process, aimed both at providing inputs to policymakers and at advancing knowledge. Furthermore, it was a temporary coming together of a large number of researchers and policymakers with a common concern that transcended the bounds of STPI: how to gear science and technology more effectively toward development. A large number of the persons that became engaged in STPI had already done work in science and technology policy and most of them continued in the field after STPI was formally terminated in late 1976.

Complexity Acknowledged

From the beginning, it was accepted that the STPI project dealt with a most complex area of concern; however, acknowledging complexity and devising effective ways to handle it are two different things. At times, there was a temptation to break the problem area into self-contained, independent, and smaller subproblems that would be more manageable and to introduce assumptions that would be amenable to conventional research approaches. The scope of the research was enlarged to include considerations that are normally not regarded as part of science and technology policy, and the project was organized to bring together various disciplines and to emphasize, although to different degrees in each of the participating country teams, the connection with policymakers that provided a realistic underpinning to the research efforts.

The process of translating ideas into tools that actually influence decision-making on technological matters became the main focus of the research. The historical and economic context of industrial science and technology policies and the nature of technical change were the two anchor points preventing STPI research from drifting into the trap of producing acontextual formal findings and recommendations.

The range of scientific and technological activities that were examined as part of the STPI project went beyond traditional categories of “research and development” to include “minor” S&T activities, such as quality control, engineering, etc., which in the Third World play a most important role in the development of S&T capabilities. Furthermore, the development of an adequate human resources base was regarded as one of the major tasks in S&T development.

STPI research on the industrial sector examined a broad range of industrial and economic development policies in terms of their impact on S&T capabilities. For example, it considered large investment projects, which are one means to create a substantial demand for local S&T activities but are not usually examined in terms of their technological implications.

The initial framework of concepts and the research design prepared by representatives of international agencies was, as could be expected from an

a *priori* design, rather formalistic, borrowed heavily from the “systems approach” school of thought. Nevertheless, it offered the country teams a starting point, one that could be changed as the research proceeded. In due course, conceptual categories were added and discarded, explanatory frameworks were introduced, and the research procedures were altered a number of times. However, the unifying concern for the STPI teams remained the process of policy implementation, and this set the bounds within which modifications were made.

Initially, an implicit belief that guided the search for knowledge about policy implementation was that policymakers’ mistakes were due to ignorance and could be reduced by information. It was believed that various parties intervening in the process of S&T development would work in harmony if they understood the direct and indirect effects of their actions. This implicit belief changed as the findings began to indicate that policies were being made and implemented with complete disregard for their technological implications and that the policymakers’ actions were not only due to ignorance but to real conflicts among the interest groups that had stakes in industrial growth. Thus, toward the end of the project, the earlier belief gave way to the belief that it was important to understand the nature of conflicts of interest and to expose the value premises on which differing viewpoints were based.

Another belief at the heart of STPI research efforts was that S&T capabilities help achieve the autonomy necessary to orient the growth of industry toward self-reliant development. A corollary to this belief was that a less-developed country must acquire a measure of control over its own technological evolution, identifying and developing industrial S&T options and determining the best course to follow. Collaboration among less-developed countries was considered essential, and the STPI project itself was one step in this direction.

Some Issues

The STPI project studied three interconnected aspects of policy design and implementation: the historic and socioeconomic background; the characteristics of state intervention; and the nature of technical change in industrial branches. Each one was correlated with the issues derived from the research findings to illuminate the contextual factors that condition the design and implementation of S&T policies and the ways in which policy instruments operate and interact with each other. The objective was to discover their impact on technical change at the industrial branch level and on the development of S&T capabilities for industry.

One of the basic premises of the research in STPI was that the specific characteristics of underdevelopment and the diversity of country contexts must be taken into account. The dynamics of history, particularly of industry and of science and education; the economic environment in which industrial growth takes place; and other cultural, social, and geographic factors condition strongly the opportunities for technological development in industry, and their influence on the effectiveness of policy instruments cannot be ignored. In fact, their importance signals the dangers of extrapolating specific findings and recommendations from one context to another. Findings do not have universal validity — at least until some general theory to interpret them is developed — but they do help focus on

relevant problems, variables, sources of influence, and possible interferences. They provide partial, highly useful knowledge that transcends different contexts, but they cannot be wholly accepted in cross-country comparisons or even in industrial-branch comparisons in the same country.

This last point deserves emphasis because of the overriding importance of focusing on the impact of S&T policies and policy instruments at the level of industrial branches. Time and again, the results obtained by the country teams showed that S&T policies designed for industry as a whole were ineffective and that policy instruments employed to effect technical change in productive units were likely to be unwieldy and difficult to operate. STPI research indicated that the traditional concept of industrial branch, as defined in economic statistics, needed to be enlarged to include government agencies, research institutes, consulting firms, financial entities, and so on.

Before the design and implementation of industrial S&T policies can be geared to local situations, there are a variety of contextual issues that need to be examined. Only the most important will be highlighted here. They are presented as questions that partially overlap, covering issues such as the emergence of industry, the relations between industry and agriculture, the importance of the foreign sector, the nature of the internal market, and so on.

How did industrialization begin? How was it sustained? and What was the role of the state in it?

In most STPI countries, industrialization began almost in an involuntary way, prompted by external crises (recessions, war) or by balance of payments difficulties that forced countries to restrict imports and to start domestic production. Then, deliberate protectionist policies were adopted to stimulate local industries; they included tariffs, import licences, foreign exchange controls, and import prohibitions. In some cases, the imposition of tariffs on imports was considered as a way of generating revenue for the government. With only recent exceptions, protectionist measures in STPI countries have not been regarded as devices to guide industrial growth but rather as corrective mechanisms to be employed in economic crises. Thus, policy instruments that protect and stimulate the growth of industry are seldom used to guide selectively the expansion of industrial activities and are used even less to stimulate the growth of specific S&T capabilities for industry.

What has been the nature of intersectorial relations during the process of industrialization?

In all STPI countries, the means for industrial growth came from the primary sector, which produced sufficient quantities to permit international exchange and to generate an economic surplus. The main burden for the support of industry fell on agricultural activities, which provided foreign exchange for the imports of machinery and intermediate products for industry; provided cheap labour (rural-urban migrants); provided the

resources necessary for many industries (textiles, food processing); and provided a profitable market for industrial products; agricultural goods were sold at a low price in contrast to the prices for industrial products from the cities. The list of agricultural contributions, which exemplify the phenomenon of resource transfer, is still applicable in STPI countries after many years of industrialization and is similar for other primary activities, such as oil production, mining, and fishing, that are export oriented.

Resource transfers have been regarded as acceptable tools for stimulating the growth of industry in less-developed countries, and they have continued indefinitely because of industry's inability to support itself. In the long run, they promote complacency, limit productivity, and even discourage the development of an indigenous technological base. In addition, continued resource transfers make industry vulnerable to fluctuations in the production and export of primary commodities.

How did the different industrial branches emerge? How did they interlink with each other over time? and How did they affect the pattern of demand for technology?

In the STPI countries, as in most less-developed countries, producers of both durable and nondurable consumer goods were the first branches of industry to emerge. They grew under the stimulus of protectionist measures that restricted the import of consumer goods and provided incentives to import the machinery and equipment to produce consumer goods. There was little protection instituted for the local manufacture of capital goods or industrial inputs. The result has been that capital goods branches have not emerged, and governments have been forced to promote them by launching special legislative measures, financing investment projects in basic industries, and generating demand for machinery and equipment produced locally.

The lopsided development of consumer goods branches of industry has implied massive imports of machinery and equipment that embody modern technology rather than technological knowledge. Thus, the knowledge has been imported separately in "disembodied" form, primarily through licencing agreements and foreign technical assistance.

How did the demand and the supply of foreign technology evolve and condition each other? and What was their impact on the growth of local technology?

When local goods are substituted for imports, they must comply with tastes and habits that have already been established and must imitate as closely as possible the goods that they are replacing. Thus, substitution industries require imported technology, machinery, and intermediate inputs. They cannot rely on the local scientific and technological base for information on how to expand their activities (with the exception of routine testing, norms, and standards, etc.); therefore, they forge strong ties with foreign suppliers of technology. The proven character of foreign technology, the fact that the foreign suppliers can guarantee continuity,

and the risk aversion of local entrepreneurs (including those in state enterprises) all reinforce the reliance on foreign sources of technology.

There were other mechanisms at work that cemented the ties with foreign producers, the most important of which was foreign financing. When financing for industrial projects was obtained from abroad — through bilateral government credits, multilateral agencies, or private banks — the use of foreign technology, equipment, machinery, and engineering services usually was a condition for granting the loan, and there was little opportunity for local engineering or research groups to participate.

Finally, the expansion of direct foreign investment, mainly through transnational corporations, made the ties between local industry in less-developed countries and the suppliers of technology from the industrialized world even stronger. The leading role played by transnational corporations in many industrial branches has been reflected not only in their share of the market but also in the technological trends that they imposed.

The pressure of foreign technology led to impassivity on the part of local entrepreneurs who made few efforts to diversify sources of supply or to evaluate the foreign technology being offered. Needless to say, potential local resources (if they could be said to exist) were ignored, and local industry became totally dependent on foreign technology and rather vulnerable. Although technology imports do not always hamper the growth of domestic S&T capabilities, the wholesale importation of technology without efforts to screen, control, and absorb it usually stunts the growth of domestic S&T capabilities. Thus the problem is not one of cutting the inflow of foreign technology but rather of regulating it. The high degree of dependence on foreign technology is not an exclusive characteristic of import substitution industries. When an export-oriented strategy is followed, the technology required to manufacture goods for export is usually imported, and the ties with foreign markets are strong.

How have foreign sectors influenced industrialization and technological capabilities?

Most less-developed countries, and all of those in the STPI project, are open economies in which the foreign sectors play a significant role. Because they are primarily exporters of primary commodities or exporters of other goods with narrow domestic markets, they are highly dependent on foreign trade and foreign transfers of resources for industrial expansion. In fact, foreign trade upheavals were largely responsible for initiating industrialization in them.

Chronic shortages in foreign exchange have limited their capacity to import capital goods and inputs required for industrial production. Over the long-run, the shortages have acted as a limited stimulus for the local production of certain machinery and equipment, or at least the repair, maintenance, and reconstruction of imported equipment. Similarly, periods of international crisis (recessions, wars), when the supply of products to import is restricted, have also stimulated local production.

On the one hand, foreign investment has provided a large share of the capital required for the expansion of some technologically advanced

branches, and foreign loans (tied to foreign technology) have provided much of the capital for large investment projects, which are usually beyond the accumulation capacity of the less-developed countries. On the other hand, the transfers of profits, interests, royalties, technical assistance fees, and so on, from local entrepreneurs and from subsidiaries to the headquarters of transnational corporations have drained the industrial sector in less-developed countries, drawing off a substantial portion of the limited surplus that industry is capable of generating.

How has the internal market affected the growth of industry and of technological capabilities?

The structure of industry, and hence its technological characteristics, is closely related to the pattern of consumption. The size of the internal market, its relation to income distribution and concentration, and the consumption habits of the population all condition the orientation, scale, and characteristics of industry: what will be produced, for whom, in which quantity, and with which attributes. These constitute the basic or primary decisions in the development of industry — the foundation for decisions on technology. The orientation and conditioning of the overall structure of industry is seldom attempted in less-developed countries, and when attempted, is not always successful. Thus, the patterns of consumption and their evolution are left to the play of market forces, and, in consequence, technology for industrial expansion is derived from them in a haphazard way.

Industry in the less-developed countries has not evolved gradually as it did in a handful of Western countries. In the latter, productive techniques were developed and were merged with findings from scientific activities to generate science-related technologies. The whole process took a rather long time to mature. The less-developed countries did not begin to undertake directed, organized scientific and technological activities until the beginning of the 20th century, and their development has been influenced strongly by the evolution of science and technology in the industrialized countries. The lack of a continuous historical tradition in science and technology and the limited human, physical, and financial resources of most less-developed countries make it very difficult to sustain a viable scientific and technological effort. The same holds for the artisan, technical, and engineering bases, which, if viable, would permit the absorption and internalization of scientific findings for the purpose of industrial production.

The less-developed countries are now acquiring, on the one hand, an artisan, technical, and engineering base (often through the evolution of traditional technologies) and, on the other, the capacity to compete in modern science. This is a stage in which most of the industrialized countries found themselves in the second-half of the 19th and the first 2 decades of the 20th century. Thus, there is an inherent lag in science-related industries in the less-developed world, for the industrialized countries have now entered fully into the stage of systematic, organized, and mass production of new technologies based on scientific findings. Not only is the process accelerating at a rapid pace in the industrialized world but also the continuous transfer of the technologies, which result from these activities, is

stunting the development of an endogenous scientific and technological base for industry in the Third World countries.

Given the preconditions, what are the opportunities and limitations for the development of industrial S&T capabilities in the less-developed countries?

The present unequal distribution of industrial and innovative capabilities between industrialized and less-developed countries cannot be drastically altered in the short- or medium-term. The process of building up an endogenous scientific and technological base for industry is a very long one and requires determined and sustained efforts. Nevertheless, many actions could be taken in the short- and medium-run to anticipate subsequent, more substantial efforts and to ameliorate some of the harmful effects associated with indiscriminate technology imports, turning them into a positive force for the development of local S&T capabilities.

Clearly, the opportunities for improving the S&T base are bounded by the growth and evolution of industry. If industrial S&T capabilities (research and development, technical education, support services, experimentation, information, etc.) outstrip local industry, they fall into a vacuum, void of effective demand. Research institutions become self-centred; skilled personnel emigrate, and resources are wasted producing an infrastructure that cannot be put to effective use. More often, the case is that industry surpasses the local S&T capabilities for generating new technology and absorbing imported technology. For example, turnkey plants are often imported in package form, ensuring productive capacity but effectively blocking the development of corresponding technological capacities. Thus, the problem is one of balancing the development of industrial production with that of an S&T capacity so that one reinforces the other. In this process, the human resources development, engineering activities, and the development of an engineering science base that can absorb imported technology become, perhaps, more important than the growth of a local basic and applied research capacity, at least in the initial stages. Once an engineering base has been acquired, emphasis can shift toward research and development.

To consider the development of industrial science and technology independently from the growth of industry amounts to idle speculation, and, thus, S&T policies must be integrated with industrial development policies. The question is: how can the limited opportunities that are available be exploited to the fullest possible extent? The first step is to promote political, managerial, and technobureaucratic groups who share a common view of the development of industry and of the role of technology in it and who can bring pressure to bear for the growth of industry-related science and engineering.

In general, policy instruments have been employed to promote the expansion of industry but seldom to orient the pattern of consumption and the corresponding industrial structure. There have been some exceptions, many of which were urgent actions for specific industries, responding to the interests of influential pressure groups. For example, among the STPI countries, measures were aimed at reducing the cost

of labour (subsidies and tax rebates on payrolls to encourage industrial employment, training of the labour force in government organizations); reducing the cost of capital (easy credit terms for industry, tax incentives to promote investment); providing basic services and industrial inputs at low cost (energy, water, transport, communications, iron, and steel); and restricting imports of competing goods (tariffs, import licences, foreign exchange controls). The measures usually applied to both local- and foreign-owned enterprises, even though the former were sometimes given more support.

Countries that do not have a well-defined and discriminating industrialization strategy have only vague S&T policies, of a general supportive nature, and do not have strong policy instruments. They usually offer incentives and inducements that encourage a general infrastructure for industrial S&T but are incapable of guiding the development of scientific and technological capabilities for industry. The converse is also true: countries that have defined an industrialization strategy, established priorities, and determined the scope and nature of government intervention have formulated S&T policies that correspond to the aims of industrial development.

Explicit science and technology instruments are those intended to affect directly the decisions having to do with the growth of local S&T capabilities; implicit ones are those that affect decision-making indirectly through second-order effects. The great weight, both in number and influence, of the latter limits the potential impact of the former. For this reason, when studying their impact on the development of S&T capabilities, the analysis gravitates naturally toward implicit S&T policies, even though one of the central aims of S&T policy formulation may be to align explicit and implicit policies.

A basic issue is whether policy instruments used to implement industrial development policies have any impact on the behaviour of productive units. Unfortunately, at times, the array of policy instruments has been designed with little knowledge, or with a very naive understanding, of the nature of industrial productive activities, the rationality of entrepreneurs, or the forces orienting the expansion of industry. The result is that policies and policy instruments are formally superimposed on an industrial structure that does not respond to the prescriptive, motivating, or coercive measures they contain: although policy instruments are designed and implemented according to an assumed or perceived reality by government, often industry operates according to a different logic and responds to different stimuli.

The pitfalls involved in policymaking and legislating without considering the inner workings of industry and the complex and conflicting interests and pressures that shape its evolution are reflected in the irrelevance and the impotence of policy instruments.

Clearly, the design and operation of precise and accurate policy instruments that produce the desired effects in a straightforward manner remain a technocratic illusion. Most often, policy instruments do not have the influence they are supposed to have because of the many factors intervening, the conflicting sources of influence, or the practical problems in implementing them.

This should not be interpreted as a cause for despair but as a plea for deeper understanding and less formalism. There are many examples of

policy instruments of various types that have been successful in developing industrial S&T capabilities. All have been designed and implemented with full awareness of the opportunities, limitations, conflicting interests, and real possibilities to effect change.

Policy Implementation

It is difficult to characterize S&T policy instruments individually, and in any case, it is more important to examine their interactions. As a whole, the policy instruments, both explicit and implicit, exhibit several characteristics, some of which define the style of policy implementation. The findings in the STPI project highlighted several general characteristics that merit attention.

Generality: The majority of the policy instruments identified in the STPI project were general, their impact to be felt in decisions regarding overall industrial growth and in inter-branch decisions (e.g., incentives to promote investments, tariff structures to foster the growth of certain branches). The greatest proportion applied across the board to all industrial branches and all types of enterprises regardless of the products they manufactured or the technologies they used. Thus, the impression that remains is one of policy instruments lacking the necessary selectivity to orient the growth of industrial S&T capabilities. An assumption underlying the sweeping policies is that all branches of industry and all types of enterprises are equally important and that the reasons for the behaviour of the different types of firms and branches are all the same.

Some policy instruments are designed in such a way that discretionary power is vested in the government agencies that are in charge of applying them. In theory, the agency's authority counteracts the generality of the policy instruments, according to the peculiarities of each case. The problem is that the lack of well-defined criteria for the use of discretionary power has in fact precluded more selective use of policy instruments. For example, the registries of licencing agreements, which were designed to regulate technology imports and which gave discretionary power to the officials approving the agreements, have seldom been used to regulate the flow of imported technology in accordance with industrial development strategies, precisely because of the lack of well-defined industrial policies and the consequent impossibility of establishing criteria for screening and approving licencing agreements.

Heterogeneity: In most STPI countries, many policy instruments of various types, responding to different policy orientations and assuming different forms of rationality of industrial enterprises, were found coexisting, even though they all were not actually used. The diversity in the array of policy instruments did not alter their generality, for most of them, however different, were general in terms of their effects on technological decisions. The heterogeneity has been a consequence of the temporary presence in government of certain power groups seeking to advance the policies they propose but leaving the preceding structure of policy design virtually unchanged. Thus, in some countries it is possible to find different vintages of policy instruments, of which only the latest are put into practice.

The heterogeneity of policy instruments has sometimes derived from power conflicts within the state. The government itself is not homogenous and may include competing groups who influence the use of policy instruments for their own purposes. The result is a rather mixed set of policy instruments and a collage of criteria used to put them into practice. The effects are most noticeable when policy instruments involve discretionary power, when several agencies are involved, and when there is a lack of coordination in the application of policy instruments. The lack of administrative continuity and the erratic behaviour of government agencies in charge of policy instruments also contribute to the heterogeneity of the array of policy instruments and lead to contradictions in their operation.

Closely related to heterogeneity in policy implementation and contributing strongly to it is the instability and vacillation of industrial development policies. Although flexibility is desirable, most often the tenuous nature of policy instruments is not planned. There are, however, a few cases in which policy instruments have been designed in accordance with the different phases of industrialization, new instruments superseding outdated ones as the process of industrialization advances.

Passivity: The majority of policy instruments identified in STPI were passive, i.e., the agency in charge did not initiate the actual application of the instrument; rather, the onus was on the productive units, research organizations, engineering firms, etc. that were to be affected by them. The passivity was intimately tied to the nature of the instruments, which primarily provided incentives to the industrial firms. The effectiveness of passive instruments is often limited because the intended beneficiaries are unaware of them. STPI findings were that relatively few enterprises took advantage of the opportunities offered by the policy instruments and thus a small number of industrial firms accounted for a large share of the benefits. The majority of enterprises were not affected by government measures and worked without paying attention to them; therefore the benefits were poorly distributed and marginal. Furthermore, the conditions for the application of instruments were often defined in such a complex way that they became irrelevant to all but a small number of large industrial enterprises having the means to apply for and secure the benefits.

Redundancy: There are a large number of policy instruments aiming at a common goal, such as conferring benefits on industrial enterprises, and these are redundant. For example, the STPI project discovered that countries often had many instruments designed to lower the cost of capital for enterprises (various types of special credit lines, tax rebates on interest payments, low tariffs for the import of capital goods, special tax exemptions for reinvesting profits, accelerated depreciation rates, special tax credits for investment in certain regions, basic infrastructure services provided by the state, and so on). Even though each of the instruments has a special purpose, their combined effect limits any inherent selectivity. Practically any industrial firm can benefit from several of them, and some firms will seek to benefit from most of them. In this way, large enterprises with the means to take advantage of the measures can easily reap a disproportionate number of the benefits.

Incompleteness: Incompleteness is a characteristic most often found in policy instruments that are supposed to restrict and to control the behaviour of industrial firms (e.g., import restrictions, foreign exchange controls, registry and approval of licencing agreements, etc.). According to STPI findings, most negative instruments did not cover the whole range of productive units; they left ample room for exceptions; and state enterprises were particularly prone to circumvent the regulations that were designed to stimulate the growth of local industry and foster the development of indigenous technological capabilities. For example, import prohibitions intended to promote local production were often ignored or revoked by state enterprises or government agencies, and the same applied to the signing of licencing agreements containing restrictive clauses forbidden by existing legislation. Thus, negative policy instruments were found to be incomplete and likely to be circumvented through exceptions.

Formalism: Most of the primary decisions, referring to the choice of products and also to the choice of policy technologies to manufacture them, are not influenced by the array of policy instruments and are the result of other forces at play. Policy instruments intended to develop S&T capabilities, and particularly the explicit ones, focus on the formal or secondary aspects of decisions to incorporate technology into productive activities: they affect the conditions under which decisions are put into effect but not decision-making.

Most policy instruments, both positive and negative, could be removed without affecting the basic decisions taken by enterprises. For example, if an enterprise is already convinced of the value of research and development activities, it will carry them out regardless of the existence of tax incentives for research activities, and, conversely, tax incentives will not prompt an enterprise to undertake research. Policy instruments do not affect an enterprise's competitive position and profitability sufficiently to induce a change of attitude on the part of entrepreneurs. Registries of licencing agreements are a good example. Whereas they are supposed to eliminate restrictive clauses in technology-sharing agreements, they only have control over the formal contract. A potential licensee who needs technology is in fact at the mercy of the licencer who has the technology. No amount of government intervention can restrict the pressures imposed by a licencer, and most licensees submit voluntarily to the demands, although the formal contract may not reflect any controls.

There are other inadequacies in present S&T policy instruments that need to be examined, including the time it takes a particular policy instrument to have an impact, but, first, a more detailed analysis of individual policy instruments is required to appreciate fully the opportunities and problems involved in their application. Based on their impact on the development of science and technology capabilities, there are five categories of policy instruments: those that promote the demand for local technology; those that develop an S&T infrastructure and generate local technology; those that promote the absorption of technology by industrial firms; those that regulate technology imports; and those that promote S&T enterprises. A few key policy instruments merit individual attention because of their relatively stronger impact; these include industrial financing, state enterprises, S&T planning, fiscal measures, import

controls, research and development institutes, registries of licencing agreements, and so on.

The way in which policy instruments actually influence development of S&T capabilities for industry also deserves attention; otherwise the study of policy instruments remains abstract. Some of the questions that need to be answered are: What is the differential impact of various policy instruments on technical change at the enterprise level? What other sources of influence mediate the impact of policy instruments? On which specific decisions do S&T policy instruments act? What has been the impact of industrial S&T policy instruments in orienting and shaping technological change? These questions cannot be answered by looking at the functioning of policy instruments alone; they require an understanding of the process of technical change and innovation in industrial enterprises.

Technical Change

Policy instruments do not affect technological change at the branch and enterprise level in a linear, straightforward manner; in fact there are many complex factors and conflicting sources of influence intervening in the process of S&T policy design and implementation. In addition to the context of industrial development and the functioning of the government machinery, the orientation and pace of technical change in itself is a key to understanding the possible impact of policy instruments. The experience in STPI suggests that the appropriate level of analysis is the industrial branch even though the opportunities and constraints within a particular branch are not the same for all enterprises and the impact of policy instruments will vary accordingly. The STPI findings indicate that the design, implementation, and impact of policy instruments cannot be studied at the level of industry as a whole nor at the level of a particular enterprise.

An issue that must be kept in mind when examining the impact of policy instruments on technical change is that the technological innovations introduced in the less-developed countries originate, for the most part, in the industrialized countries. In the latter, technical improvements result from the interaction of factor endowments, market forces, and competitive strategies. For this reason, the range of industrial technologies at the disposal of the less-developed countries is determined externally, even though the selection of a specific technology and the possibilities for absorbing and improving it still leave room for shaping the local technological base.

The STPI studies on technical change and the impact of policy instruments point out certain key paths or sequences that link macroeconomic conditions and variables with technological decisions within each firm. These paths define the pattern of interaction between context, economic conditions, the characteristics of industrial branches, and technological decision-making by industrial firms; they show the differential impact of S&T policy instruments during the chain of events and indicate the most effective means of linking macro with micro phenomena.

There are three categories of factors that must be taken into consideration when examining the impact of S&T policy instruments on technical change at the industrial branch level: the characteristics of the

technology itself and the nature of the technical changes taking place; the structural and dynamic characteristics of the industrial branch; and the main features of the enterprises. The order of importance of the factors depends on perspective, i.e., engineers privilege the nature of technical change, economists the structure of the branch, and sociologists the characteristics of the enterprise and the entrepreneurs. Participants in the STPI project agreed on the combined importance of the three categories but could not agree on the most influential category.

The characteristics of technology and the nature of technical change can be studied from several points of view. It is possible to focus on product, process, materials, major trends, a particular innovation, a chain of productive activities, or the main way in which technology is incorporated into the productive process (through equipment and machinery, process specifications, product specifications, intermediate products, or through human resources).

The objective of analysis is to discover how technology is related to the structure of the branch and to the characteristics of the enterprises so that the inherent constraints and limitations may be understood clearly.

The structural and dynamic characteristics of the branch involve factors such as the size and rate of growth of the market, the degree of concentration and competition in production, foreign investment, and the geographic dispersion of production. Of particular importance is the way in which a branch is articulated with the rest of industry and the economy, i.e., whether it is dependent on imported or local raw materials, inputs, and equipment; whether it is largely isolated or is closely linked to other industrial branches; whether the products are final consumption, intermediate, or basic; and so on.

The most important factor in the characteristics of the branch is the predominant form of competition among the firms and the role that technology plays as a channel or mechanism of competition. The forms of competition vary widely from branch to branch, and the role of technology changes with the structural and dynamic characteristics of a given industrial branch.

The predominant channels or mechanisms of competition include price reductions to capture a larger share of the market; product diversification to expand the existing market or create a new one; development of distribution channels to place the product close to the consumer; provision of after-sale services to secure consumer loyalty; specialization of production to exploit market niches; promotion of exports to transcend the limitations of local markets; regionalization of production to take advantage of lower transport costs; vertical integration to ensure the control of raw materials and intermediate products; introduction of new production technologies to take advantage of economies of scale, increased productivity, and of more efficient use of inputs with the aim of reducing costs; and so on. The mechanisms are combined by different firms to form their competition strategies. The predominant form of competition resulting from the interaction among firms decides the relative importance of technical change in the strategies of individual firms, and, in consequence, the impact that the different policy instruments are likely to have on the development of S&T capabilities in the branch.

The characteristics of the enterprises constituting the branch are also important. They emerge not only as a result of a firm's competition strategy but also as a statement of its size, ownership, location, degree of technical expertise, financial structure, and managerial attitudes. The factors strongly affect a firm's decision to introduce a particular technical innovation, the sources from which it will be obtained, the way in which it is to be incorporated into the productive process, and so on. In the last analysis, the building up of technical capabilities in industry can only be achieved through the aggregated upgrading of individual enterprises and other organizations and agencies involved in industrial science and technology.

The factors within the three categories interact with each other to mould technological evolution and to condition the impact of S&T policy instruments. At present, the interactions are abstract and are a long way from providing a satisfactory theory of technical change in less-developed countries. However, the framework of the three categories and the factors that have been identified in each provide a guide to the identification of major conditioners of technical change in industry and of the impact of S&T instruments.

Explicit Instruments Lack Impact

The empirical evidence gathered in the STPI project shows overwhelmingly that the explicit S&T policy instruments (with the exception of personnel training) have little impact on technological change, particularly at the early stages of industrialization. The interactions among the three categories are themselves the main determinants of technological change in industry and of the development of industrial S&T capabilities.

Furthermore, it was found that enterprises often make technological decisions without a consideration of S&T policy instruments. After decisions have been made, the firms either take advantage of the benefits or look for ways of getting around the penalties specified in the instruments.

To date, policy instruments have not exerted much pressure on technical change in enterprises and branches, but at times they have had a powerful impact on the development of an infrastructure to perform science and technology activities. S&T infrastructures have been successfully developed in some cases, ostensibly for industry, and have been primarily the product of explicit government intervention. However, the capacity to perform scientific and technological activities has tended to grow and remain in isolation. The institutions that compose it are serving the whole industry or particular branches and are not able to meet the specific demands posed by individual firms. Thus, the response capacity of the S&T infrastructure has been geared to general activities in S&T, i.e., those that are common to a variety of industries and to different enterprises in a given branch.

Nevertheless, S&T capabilities are one of the keys to directing industrial development. Less-developed countries that value national autonomy must acquire the ability to evaluate, choose, and absorb imported technology and to generate local technology, transforming it into viable industrial projects. This capacity is dependent on a country's own industrial S&T capabilities.

Furthermore, as development proceeds and a country becomes able to accumulate income and an economic surplus, it will only be able to invest its

surplus internally if it has suitable S&T capabilities, a thriving capital goods industry, and policies that support local technology and the capital goods industry.

Essential Ingredients in S&T Policymaking

The development of S&T capabilities and of an endogenous scientific and technological base for industry will take very long for most less-developed countries, but development (whichever political or social form it takes) is not viable if the potential benefits of modern science and technology are rejected: science and technology are necessary components of any development strategy in the last third of the 20th century, although the Western style of S&T development is not the only way. There is room for choice, albeit limited, in the sequence of steps and the particular ways science and technology are to be used.

At present, the West commands disproportionately the S&T endowments; the possibilities of rapidly or radically changing the disparities are minimal. However, the margin for maneuver within the absolute constraints is certainly larger than perceived by most leaders from the less-developed world.

The upheavals of the Western industrialized economies in the 1970s and the international redistribution of industrial activities may signal new opportunities for the less-developed countries. A country's ability to respond will depend largely on its strategies of industrial S&T development. It must delineate areas in which local S&T capabilities are to be developed fully and indigenous technologies made the basis of productive activities; areas in which capabilities for choosing, modifying, and absorbing imported technologies must be built up; and areas in which the existing base of traditional technologies must be preserved and developed further.

The policies are bound to fail, regardless of good intentions, unless they are embedded in a context that favours S&T development; unless they are closely articulated with industrial development policies; and unless they acknowledge and incorporate the characteristics of technological change, of the industrial branch structure, and of the enterprises in particular branches of industry. Thus, they must be designed to suit the specific needs and situations in which they will be applied.

The only generalization, therefore, that emerges out of the research in STPI is that S&T policies and policy instruments must be specific. There is a need to avoid sweeping generalizations and the elaboration of "standard" models or frameworks for S&T policy design and implementation. There are many pitfalls associated with disregarding the specific contexts of underdevelopment or overlooking the full range of factors, both internal and external, that condition the development of indigenous S&T policies.

Finally, in learning about the process of S&T development in a given country, it is necessary to avoid simplistic conceptualizations borrowed from one discipline or another, combining instead various research approaches, disciplinary perspectives, and ideological points of view to apprehend the interplay of forces and interests that shape S&T development. Considering the diversity of contexts of underdevelopment,

there is no substitute for determined local efforts — however modest at the beginning — to understand the particular situation of industry and of S&T capabilities, their possible future development, and the types of government measures that are likely to be most effective.

PART 2

Comparative Analysis

Chapter 1 The Project

The Science and Technology Policy Instruments (STPI) project was in many respects unique. For 3 years, it linked more than 150 researchers from institutions in 10 less-developed countries (Argentina, Brazil, Colombia, Egypt, India, Mexico, South Korea, Peru, Venezuela, and the Republic of Macedonia in Yugoslavia); it generated knowledge and information that in many instances were used directly by policymakers; and it showed that a large, temporary research project yielding practical results can be organized and managed in Third World countries.

STPI consisted of a loosely structured network of research teams¹ from countries with different cultures, levels of development, political systems, and ideologies. The researchers on the teams represented a variety of institutions and a multiplicity of roles in policymaking. They also represented different levels of experience and seniority as well as different professions and disciplines. There were also marked differences in personalities, ways of thinking, and — as in any large undertaking — degrees of commitment to the project and reasons for joining. The cohesive element was a common desire to examine ways and means of exploiting science and technology for development objectives in the industrial sector.

The idea for the project originated in

¹ For a list of the participating institutions see Appendix, p. 102.

February 1971 at a meeting of representatives of Latin American science policy organizations. The participants believed a situation had been reached where many policy recommendations had been made by national experts, international organizations, and academic institutions for the development of science and technology but there was practically no information about how to put them into practice and make them work. It was noted that government agencies had an array of well-defined legislative, institutional, and operational measures, i.e., policy instruments, to reflect, for example, monetary policies but had no comparable instruments to reflect science and technology policy.

The initial idea was to survey and compare the ways in which different less-developed countries approached the design and implementation of science and technology policies. The goal was to help planners and decision-makers choose the most appropriate way of tackling the problem in their own countries. In 1971, when several international organizations were contacted for project support, both the Department of Scientific Affairs of the Organization of American States (OAS) and the International Development Research Centre (IDRC) of Canada showed interest in sponsoring a project in the area. Background reports were prepared and feasibility studies were conducted in Peru and Argentina during 1972. The results of these studies, together with a draft proposal, were

considered at a meeting convened by the IDRC in Barbados in January 1973. Participants from 10 countries attended the meeting and later submitted research proposals to their respective institutions for approval and to the IDRC and the OAS for possible funding. Nine countries decided to join the project, and subsequently two more were added, although one dropped out in mid-1974. The two funding agencies responded positively, with the IDRC contributing substantially to cover the costs of the 10 national teams and the OAS underwriting some of the costs of Brazil, Colombia, Mexico, and Venezuela.

The project effectively began during the second half of 1973, when most of the country teams were formed and the field coordinator's office was set up in Lima. Each team was headed by a coordinator, who was a member of the coordinating committee (see Appendix I). The first coordinating committee meeting was held in August 1973, and most of the country teams were fully operational by January 1974 and had launched their research efforts. Then in the middle of 1976, a workshop was held at the University of Sussex to discuss the results obtained by the country teams and to outline the final comparative reports. Not all the teams finished their work in time for the Sussex workshop, and several of them continued their research into 1977 and the first half of 1978.

The goals of the research evolved during the lifetime of the STPI project. Originally, the intention was to prepare a dictionary of policy instruments describing the tools at the disposal of the planner or government decision-maker. However, the participants found the approach to be excessively formal and preferred to compile case studies focusing on a particular context and on the functioning of a few selected policy instruments. At the Barbados meeting, they agreed on a balanced approach: to complete individual country studies sharing a common framework of concepts and concerns.

At the beginning of the STPI project, the plan was to conduct a series of country studies that would produce results of direct value to policymakers in each country and as a secondary objective to produce material for an international comparative report.

The plan changed as the research took shape and as new governments and policies emerged in several countries. In one country, practical research was minimized in favour of academic content; in others, the opposite was

true, and the results of research were used directly by policymakers. Most of the teams tried in their own way to strike a balance between the academic and practical components.

While increasing the project's national focus, the changes limited its use as a tool for cross-national comparison and for the synthesis of country reports. Participants at the Barbados meeting even rejected the option of having common research methods to be closely supervised by the international coordinator. They pointed out that the inherent procedural and conceptual rigidities would reduce the project's potential usefulness to policymakers at the national level.

The Approach

All the participants in the STPI project had a common objective: to gather, analyze, evaluate, and generate information that would help policymakers, planners, and decision-makers in reorienting science and technology toward development objectives. The industrial sector was chosen as the primary field of inquiry to make the research tasks manageable.

To realize the objective, the project had to:

- Examine the general roles that science and technology play in attaining development goals in different socioeconomic and political systems, i.e., undertake a study of the scientific and technological network and its relation to the national economy and industry in particular.
- Identify — by analyzing the technological behaviour of government agencies, productive units, research institutes, and other organizations in science and technology — the major instruments and mechanisms that are most likely to be effective in implementing science and technology policy in a particular context.
- Study technical change at the enterprise level in several branches of industry to compare influence of policy instruments with other factors affecting technological decisions.
- Examine the major controls, practices, and procedures of government agencies that decide science and technology policy. (This

required a detailed study of government machinery and of officials' behaviour when enforcing controls.)

The complexity of the subject and the wide coverage that was required to deal with it were underestimated at the beginning of the project. Many issues associated with the main line of work on policy instruments needed to be investigated, and the participants required several background reports including technological dependence/self-reliance; technology policies in the People's Republic of China; science and technology planning; technology policies in post-war Japan; technology transfer; development of consulting and engineering design capabilities; role of state enterprises in technology policies; and constraints imposed on the design of policies by the nature of technologies.

The central line of research on policy instruments generated many detailed studies — a large body of empirical material gathered through the efforts of the teams in the STPI network. No comparative report can do justice to the amount and diversity of the material produced.

The research was action-oriented, aimed at directly supporting policymaking, decision-making, and planning activities. It required a departure from academic social science research, and the action it demanded was interpreted differently among the country teams.

The research focused not on policy formulation at the macro level nor on technical change at the micro level, but rather on interrelations between the two — a rather elusive focus, which created many conceptual and practical problems in the project. The methods guidelines² provided some means for dealing with this problem, but they needed to be modified extensively by the country teams.

The research was designed to study science and technology policy in each country, considering both the history and the environment in which policies are designed and put into practice.

The researchers represented multiple disciplines and institutional interests. Most of the teams comprised engineers and

economists, and some included scientists, sociologists, and lawyers. The teams were careful to avoid representing only a single discipline.

Although there was always one host institution where the country team was located, other organizations intervened in practically all cases, some in an active way and some by providing access to data or information. In at least two countries, the research team acted as a catalyst to bring together several national agencies that were working independently in the field of technology policy.

Those participating in the project desired to learn from the experience and to establish a network of personal and professional relationships that would continue indefinitely; toward this end, they undertook field-work, exchanged experiences, and visited other countries.

Key Concepts and Categories Used

The main concern of the STPI project was to determine what and how different factors influence the generation, diffusion, transfer, and utilization of scientific and technical knowledge in industry as a whole and within its branches. The basic idea was to explore the possible causes and effects systematically and to generate hypotheses that better explain science and technology functions and activities. For this purpose, a set of S&T functions and activities was defined, and three categories of sources of influence were identified and modified as the research proceeded.

The set of functions and activities comprised all the steps in the generation, modification, and distribution of scientific and technological knowledge. They were classified into demand, supply, and linkage. The rationale behind the categories was that knowledge is an input in the production of goods and services, and that productive units generate an expressed need for S&T knowledge (demand), that scientific and technological knowledge can be either produced domestically or imported (supply), and that the flow of S&T knowledge between producers and users takes place through intermediaries, i.e., institutions (linkage). Policy instruments act upon functions and activities in these three areas.

Productive units may demand knowledge

² See *Methodological Guidelines for the STPI Project*, 1976. Ottawa, International Development Research Centre, monograph IDRC-067e.

from domestic or foreign sources and may need know-how, patented knowledge, technical assistance (disembodied knowledge) or equipment and capital goods (embodied). Or they may demand the capability to improve and assimilate knowledge. The demand for knowledge may be met by conducting in-house research and development, troubleshooting, specialized maintenance, etc.; by purchasing or otherwise acquiring it; or by consulting science and technology publications.

Three groups of activities are included in the supply category. First is the generation of technology for productive activities. This is usually done by personnel in research centres and some specialized engineering design firms. Second, is the supply of scientific and technological services that allow the productive system to take advantage of knowledge generated locally or purchased abroad. Third, is the supply of skilled personnel to perform a variety of S&T functions and activities. In addition to these three groups of activities, there is the supply of knowledge incorporated or embodied in the machinery, equipment, and intermediate products used by the productive units.

Relating supply to demand and providing the channels through which knowledge can flow is linkage, which includes engineering and consulting services, regulation of technology imports, and industrial information and extension services.

Sources of Influence

Three types of sources of influence were identified by STPI personnel:

- Explicit science and technology policy and its instruments, which have the definite and identifiable purpose of affecting S&T functions and activities. An explicit science and technology policy deals with an issue in S&T, setting criteria for decision-making, objectives, and desired outcomes. A policy may have a direct impact but usually is put into practice through policy instruments.
- Implicit science and technology policy and its instruments, which affect variables outside S&T functions and activities but have an indirect influence on them. A better knowledge of implicit policies may allow their negative influence to be reduced and their positive effects increased, eventually trans-

forming them and their related instruments into purposeful indirect means for developing science and technology.

- Contextual factors — sources of influence that cannot be ascribed to current or recent government policies. They are a result of the country's history, cultural, and social features, resources, geography, etc. They cannot be rapidly changed and for the purpose of STPI research have been considered fixed. They affect S&T functions and activities by limiting the possible impact of explicit and implicit policies and their instruments.

Contextual factors may be invariant (resources, climate, size, location), superstructural (cultural traits, value norms, economic systems, etc.) or policy-dependent (for example, characteristics of the industrial structure arising from import substitution policies).

The three sources of influence were considered the independent variables in the STPI project. Research efforts centred on the analysis of explicit and implicit policies, their interactions, and the policy instruments associated with them. Policy-dependent factors were also looked at and several of them were dealt with in detail because of their impact on the design and operation of policy instruments and on technological behaviour.

S&T Policies and Policy Instruments

A policy can be defined as a statement of government intentions, which is set out by a high-level government official or institution (such as a ministry or a planning agency); it expresses a purpose and may set objectives, desired outcomes, and even establish targets. Policies provide criteria for generating and choosing among alternatives in the performance of functions and activities and, thus, guide decision-making. Although policies primarily correspond to the interests of government officials, in countries where the private sector has a significant influence, policies may also be formulated by representatives of the private sector.

Because a policy is only a statement of intentions, it needs to be supported by policy instruments — means by which it is put into practice. Policy instruments are the vehicle used by policymakers to orient other peoples' decision-making. Thus, policy instruments are

supposed to induce individuals and institutions to make decisions following the lines established by those in power: in short, the connecting link between the purpose expressed in a policy and its actualization.

A policy instrument is called direct when it refers explicitly to S&T functions and activities and indirect when, although referring primarily to policies, functions, and activities other than science and technology, it has an important indirect effect on them.

An instrument is a complex entity comprising one or more of the following components:

- A legal device, which may also be called the legal instrument. This embodies the policy, or parts of it, in the form of a law, decree, resolution, or regulation. Formal agreements and contracts may also be considered here. The legal device goes beyond a policy and stipulates obligations, rights, rewards, and penalties connected with its being observed.

- An organization, which is put in charge of implementing the policy. This includes not only the formal institution but also, the procedures, methods, decisions, criteria, and programs operating within the institution. The latter are administrative and technical, specifying the steps that must be carried out in applying a policy.

- A set of operational mechanisms, which are the levers, or actual means, through which the organization makes decisions and attempts to obtain the desired effect specified in the policy.

Policy instruments that do not have all three components give rise to some anomalies in the implementation of policies.

Policy instruments seldom act in isolation. Usually all the instruments associated with a given policy interact closely causing a variety of effects. This is called a *policy-oriented cluster of instruments*. Sometimes, several policy instruments associated with different policies all have effects on a particular S&T function or activity. This is called a *function-oriented cluster of instruments*. Most of the analysis of policy instruments in STPI was done using the concept of cluster of instruments as the basic category.

In practice, a policy instrument does not remain fixed but evolves through a series of stages, eventually becomes obsolete, and is replaced by another one. In this process, the agents in charge of operating it, who may be called the *policy keepers*, play a most important role.

Assessing the performance of an instrument of science and technology policy is a rather difficult task. Some of the criteria that may be employed in an evaluation refer to the range of S&T functions affected (specificity); the proportion of productive units, government agencies, research organizations, etc. it affects (coverage); the impact on units that have similar characteristics (equity); the relation between the effort required to operate the instrument and the results it produces (efficiency); and other characteristics such as flexibility, time lags, degree of stability, information requirements, and so on.

The evaluation of policy instruments in the STPI project has been a task as complex as was anticipated, and there are few instances where a clear-cut evaluation was possible. A major problem was to extricate the policy instrument from the policy itself, because of their interdependence. At times, it was found that policy instruments had been created, but no policies had been formulated. A yardstick of effectiveness for policy instruments was elusive, particularly because effectiveness is highly dependent on the performance of the policy keepers.

Policy instruments are often designed to influence more than one S&T function, and they may be successful in varying degrees. Therefore, it may be necessary to examine the effectiveness of an instrument as a whole, considering the several functions it should affect and also the positive or negative side effects it may have on activities and decisions in fields other than science and technology.

The problems in evaluating a single policy instrument are usually compounded several times over, because, in practice, instruments appear in clusters. A policy instrument often cannot be evaluated adequately unless a whole cluster is taken into consideration.

The Industrial Branch

During the empirical phases of STPI research, when interviews were being conducted to determine the impact of policy

instruments on technological behaviour, it became necessary to focus more precisely on certain industrial branches and their enterprises, research centres, engineering firms, etc. The STPI use of the term *branch* differed from normal use in economics and industry. For STPI, an industrial branch was defined as the collection of productive, supply, linkage, and service units that interact closely to form a relatively coherent whole. The productive units are grouped according to criteria such as the products manufactured, the degree of vertical integration, technology, etc. The supply, linkage, and service units are determined by their interactions with the productive units. Government agencies with policy-related functions are included among the service units.

Interactions take place not only among productive and supply, linkage, and service units, but also among the productive units themselves. These interactions may be a source of cooperation and interdependence or of competition and conflict. The degree of interconnectedness of all types of units makes the branch the most appropriate unit of analysis for technology policy.

A branch may be more or less well structured, depending on whether all the units that are deemed relevant for its functioning are present, and on whether all the necessary interactions are established. The completeness of the branch and its missing units or interactions can thus be assessed and identified.

The technological behaviour of a branch results from technological decisions taken. The impact of policy instruments on technological behaviour can be examined through the estimation of parameters such as productivity indexes, relative importance of local and foreign sources of technology, rate of increase of local organized technical capabilities, sources of raw materials and intermediate products, and so on.

Technological Behaviour

Technological behaviour can be considered as one manifestation of the interactions between the productive unit and its environment, including the branch containing the unit, the industrial sector, and the whole economy. A productive unit's behaviour results from entrepreneurial decisions in fields such as financing, procurement, labour, market strategy, etc.,

and its technological behaviour is the result of decisions relating to technology. The components of technological behaviour in enterprises are, thus, technological decisions, which for analytic purposes can be classified into primary and secondary decisions.

Primary and Secondary Decisions

The primary decisions are those affecting quality and quantity in production and the production process, that is, transforming inputs into the output mix. There is a close connection between technological decisions and the choice of goods and services to be produced. Secondary technological decisions are those affecting the capacity to transform inputs into outputs and the way in which this capacity is incorporated into the production process and then utilized. They include, among others, the choice of channels to acquire technology, the choice of suppliers of equipment and inputs, and the decision on the performance of activities such as maintenance, repair, and quality control. Secondary technological decisions also include those relating to the organization and management of the productive unit.

The effects of all types of decisions can be observed in the pattern of demand for technological knowledge and the technology absorption capacity of the enterprise. The demand for technology refers to the knowledge needed by the enterprise to improve and develop products and processes. This knowledge may be domestic or foreign and may be embodied in capital goods, intermediate products, operations manuals, or may be provided by technicians and experts. The absorption capacity depends particularly on decisions regarding the assimilation and improvement of the technology already incorporated.

Productive Units' Behaviour

To conceptualize the technological behaviour of productive units, information may be gathered on the characteristics of the product mix (type of goods, quality levels, market being served, etc.); the characteristics of the technology used; the origin of the technology used (sources of capital goods, of intermediate products, of technical assistance, etc.); the form in which the technology is acquired; the technical capabilities within the firm (maintenance facilities,

research and development activities, engineering and quality control, etc.); the firm's capacity to define, contract out, and evaluate the results of technological activities and services; the attitude of managers and directors toward technological innovation, their degree of confidence in local technical abilities, and so on.

Other Influences

The changes in an enterprise's technological behaviour that are induced by a given policy instrument are an indication of the instrument's impact; however, they are influenced by other environmental and internal characteristics. The task is to single out the impact due to policy instruments, separating it from the effects of other factors. Using the method suggested by STPI personnel, it is possible to identify explicit policies, implicit policies, and contextual factors among the sources of influence.

The set of contextual factors includes the invariant contextual factors (geography, climate, etc.), which probably affect the enterprise indirectly through their influence on the economy as a whole; the super-structure contextual factors, which define the social and cultural milieu in which the enterprise operates (such as attitudes toward work, educational levels, etc.); and the policy-dependent contextual factors that are the result of cumulative policymaking over a long period (such as the enterprise's relatively easy economic climate resulting from indiscriminate protection).

Explicit policies and their instruments are those relating to the performance of S&T activities in the enterprise, the control and regulation of technology imports, the provision of engineering design services, etc. Implicit policies are the financial, labour, fiscal, pricing, location, foreign investment, and other decisions made by the government that indirectly condition the technological behaviour of productive units.

Other contextual influences that were identified by STPI are the structure and characteristics of the branch to which the enterprise belongs and the internal structure of the enterprise as well as its technological capabilities. The former is closely related to the concept of technological behaviour of the branch. The configuration of the branch, the degree and nature of interaction among its

productive units, and the number and characteristics of units in the branch all exert influence on the way the enterprise behaves. The latter also conditions and limits the enterprise's behaviour. The way in which the enterprise organizes its technical personnel; the existing stock of technology embodied in capital equipment; the existing capacity for problem-solving and for quality control, research, and adaptation; the ownership; and the composition and attitudes of the executive and professional staff are all influential.

The task of identifying the impact of policy instruments is clearly not an easy one. Nevertheless, it was attempted and completed in STPI with varying degrees of success.

Behaviour of Research Centres

The research centres were considered the archetype in the supply of local technology. The concept of *research centre* includes organizations such as independent contract research units, university laboratories, research units within enterprises, collaborative research units formed by several enterprises, government laboratories, and so on.

Research centres are subject to the same type of pressures and influences as enterprises: contextual factors, explicit and implicit policy instruments.

The scientific and technological behaviour of a research centre is a manifestation of the decisions to identify, formulate, approve, conduct, monitor, and evaluate research projects — the research project or program being the basic unit for technological decision-making in research centres.

The study of a research centre can focus on issues such as the historical evolution of the centre, its objectives, the nature of the demand for its services, the financing patterns, the quality of its staff, the internal organization, and the institution's self-image. In STPI, because the focus was on industrial enterprises, few teams examined the technological behaviour of research centres.

Units in Linkage

Units in linkage are all the institutions and mechanisms that link productive units with the units supplying technology. They either find available solutions to the needs of productive units or have them produced by the supply units. Linkage institutions also

interpret the results of the supply units into a form that can be readily incorporated by the productive units.

The range of institutions and mechanisms in linkage is wide and varied, and the STPI researchers focused on the consulting and engineering design organization as the most important and representative. The role of engineering firms was defined, and most teams surveyed the firms and studied their behaviour to detect the policies and policy instruments that would be most appropriate for their development.

Changes in Guidelines

The key concepts used in the STPI project were a fleshed-out version of those proposed in the methods guidelines. One of the first additions was the distinction between explicit and implicit science and technology policies. The distinction was somewhat artificial because the contradictions between explicit and implicit policies disappear when explicit policies are conceived and formulated in harmony with overall industrial development objectives. Nevertheless, the research showed explicit policies to have a relatively minor impact on technological behaviour at the branch and productive unit levels, influencing only slightly the demand for technology but having greater effect on the behaviour of units supplying technology.

The initial concept of contextual factors did not distinguish between invariant, superstructural, and policy-dependent factors. STPI personnel found the distinctions worthwhile, because they found that cumulative policymaking over a relatively long period of time deserved more weight than invariant or superstructural contextual factors. The refinement of the concept allowed the teams to focus more precisely on an important source of influence and proved to be a very useful analytical tool.

When the first draft of the guidelines was prepared, the industrial branch was given little attention as an object of research. By the time the final version was prepared, the experience of some teams and their discussion of the concepts proposed initially showed the necessity of introducing the concept, to describe the unit that mediates between the industrial sector and the enterprise. The idea of "branch as a system" was put forward, and concepts such as "technological behaviour of

the branch" and "the branch as the basic unit for the design of technology policies" emerged and were incorporated.

Late in the project, the concept of "technological behaviour" proved insufficient for analytical purposes and for explaining the technological changes in enterprises. However, primarily because of time limitations, it was impossible to develop an improved concept.

Concepts whose importance was diminished during the research were those referring to supply and to research centres in particular. The few teams who pursued the theme structured the research in their own way. The STPI network considered that research centres had been frequently studied in the past, that a new approach to their evaluation was required, and that the work was outside the scope of the STPI project.

In contrast, the teams considered consulting and engineering design organizations very important and not adequately covered in previous research efforts. They focused attention on the subject, but because of time pressures, none completed their work as thoroughly as considered necessary.

In retrospect, the methods guidelines performed the function for which they were designed, providing a basis for initiating research. The country teams were able to build on this and produce a workable design.

Initial Research Design

The initial design of the STPI project was outlined at the Barbados meeting when the research proposal for the project was prepared. It drew on various contributions and draft proposals made over an 18-month period, and particularly on the feasibility studies carried out in Argentina and Peru. The initial design was the basis of the methods guidelines, which were aimed at providing the participating teams with a common set of concepts and research procedures to facilitate the exchange of experiences and results.

The STPI approach was reflected in the preparation of the guidelines in at least three ways. Theory was not stressed, and no single possibility was presented for testing. The guidelines aimed at identifying and structuring the elusive relationship between policy formation at the government level and technological behaviour at the enterprise level so that it could be researched. The

subject matter took into consideration the specific conditions of underdevelopment of the countries in the project.

The diversity of the teams, the varied contexts in which they operated, and their action-oriented approach precluded the preparation of precise instructions. Consequently, the methods guidelines sought to offer a frame of reference for translating the work of the country teams into a common language.

The research design agreed to in the Barbados project proposal and expanded in the methods guidelines included five phases:

- **Phase 1** was to provide the necessary background information for interpreting the work of later phases. It involved a description of the country's socioeconomic system, its evolution and trends, and a study of technology in industry, focusing on particular branches; it also included an investigation of the country's scientific and technological system, its links with socioeconomic development objectives, its past, and its probable future.

- **Phase 2** was to analyze policy instruments, identifying their effects as a basis for hypotheses on their behaviour. In this phase the most important influences on science and technology functions and activities were identified. Studies were made of the organizational structures that filter and mediate the sources of influences, and the sources and effects of explicit policies, implicit policies, and contextual factors were also examined. Phase 2 ended with the formulation of hypotheses that were to be tested empirically in phases 3 and 4.

- **Phase 3** was to test hypotheses concerning demand generated by branches and productive units. This phase consisted of empirical studies to measure the impact of policy instruments and contextual factors on technological behaviour. The focal points were the industrial branch and the enterprise. Two approaches were suggested for phase 3: top-down studies — identifying government policies and tracing the instruments used to implement them — and bottom-up studies, starting from decisions taken at the productive units and tracing the factors that influenced them with emphasis on policy instruments.

- **Phase 4** was to test hypotheses for units engaged in supply and linkage. Phase 4 was similar to phase 3 but focused on agencies involved in the supply of technology and its linkage with demand, including research institutes, consulting and engineering firms, registries of technology agreements, and information systems. Empirical studies were carried out on the impact of government policies and policy instruments on the local supply of technology and on the linkage between supply — both local and foreign — and demand.

- **Phase 5** was to prepare country reports and a comparative analysis. The results of the research in phases 1 through 4 provided information that was summarized by most of the country teams and served as a foundation for several international comparative reports.

The initial design was offered as a research model that could be adapted to the conditions in each country. The design was modified to various degrees by the country teams, some of them following the sequence through phases 1 to 4, others combining phases 1 and 2, some working directly on phase 3, and still others focusing on branches only and carrying out the work for all phases in each branch.

At a given time, teams were working in different phases, some teams were involved in more than one, and the variations introduced by the teams made it difficult to monitor their progress internationally.

As it happened, all the teams that completed the research went through all the phases; however, it would be highly artificial to reorder and reorganize the results to fit the initial design. Instead, results have been presented in a way that reflects the evolution of ideas and findings in STPI.

The approach adopted in the STPI project provided the opportunity to carry out a new kind of research on a large scale and to demonstrate its feasibility. However, the adoption of a particular approach means the rejection of others and imposes limits associated with the nature and characteristics of the approach chosen. Thus the STPI project had limitations, and it is worthwhile indicating the main ones.

First, there were the problems inherent in the heterogeneity of the research in various countries and the changes introduced in the methods guidelines. These have already been

discussed, and it is only necessary to add that the initial research design and the conceptual framework were perhaps excessively formal. They were formal in the sense that definitions and categories were proposed to classify data and order ideas and to organize findings, although there was no requirement to describe the inner logic or the underlying forces of the behaviour observed.

Second, problems arose from not taking the time dimension fully into account or integrating it into the research methodology. Policies and policy instruments were studied as they were operating at a given time and not monitored over a period of time. The dynamics of the country's industry and technology were taken into account, but only as antecedents to the present structure and functioning of the various sources of influence. Hence, the results of STPI do not indicate how a particular S&T function or activity evolved as a result of policy instruments and other influences. However, some of the country teams attempted to provide more than just an account of the dynamic forces leading to the present and they carefully documented and examined the evolution of policies over time.

Other problems were the result of the loosely structured framework for research in the STPI network. Although it was necessary to avoid a rigorous design, this left a gap between the abstract categories and concepts of the guidelines and the empirical data to be gathered by the country teams. No intermediate conceptual categories were offered, and they had to be developed by the individual teams to fill the gap. Some of the teams were late to realize the need for a bridge between the guidelines and the data they were collecting.

The research did not interpret the state's role in the emergence of policies and policy instruments. This would have required the extensive use of concepts such as class interests represented by the state, the origin and functions of the state in dependent capitalist economies (which most of those studied in STPI were), and so on. No theory of technical change in enterprise was postulated either. As a result, there was no unifying theoretical framework allowing all the teams to interpret the results in a clear-cut way providing a standard basis for explanation and prediction.

However, some teams began to fill in the gap between the abstract categories of the

guidelines and the concrete results of the empirical research, delineating the elements of a theory. By focusing on the policy instrument as a mediator between the collective (macro) and individual (micro) rationalities, some teams were able to lay the foundations for later theorizing that would integrate the macro and micro aspects of scientific and technological development.

Some members of the STPI network felt it necessary to go beyond science and technology and to examine the evolution of productive forces and relations of production that could provide a starting point for the study of the role of science and technology in the peripheral economies. This theme was not developed fully as part of STPI, and although a few teams made attempts at wrestling with it, it was beyond the scope of STPI's initial terms of reference.

Unraveling the Web

Placing technology at the focal point of research efforts meant that other components of socioeconomic development such as capital accumulation, industrial growth, employment, etc. were studied in terms of their impact on science and technology functions and activities and not in their own right. The aim was to unravel the web of interactions between different development policies where they have an impact on science and technology. Distortions may have resulted, but an effort was made to avoid the problems that might have arisen from ignoring the inner logic and function of the other factors.

The original design of STPI as an action-oriented research project seeking to provide answers to policymakers had a technocratic bias. Nevertheless, most of the country teams were aware of it and were able to cope with it. None had a "technocratic illusion" that blinded them to the development process in their countries. To avoid the technocratic bias totally would have required a thorough knowledge of the actors in the political process and an understanding of their motivation, both of which were beyond the framework of the STPI project.

Realizing the development potential of science and technology by designing and using appropriate policy instruments constitutes a difficult task, made more difficult by the lack of knowledge about how policies are transformed into effective action. The STPI

project, whatever its limitations, attempted to reduce the ignorance so that the real constraints would emerge in full view.

STPI worked through action-oriented research and it had limitations resulting from the degree to which knowledge and action can be effectively merged and uncertainties reduced. Clearly, STPI did not provide a final answer to any question posited either by policymakers or by academic researchers. What it sought was to develop explanations, confirmed to an acceptable degree, to reduce the uncertainty due to ignorance and help in relating knowledge to action.

Action-Oriented Research

From the early stages of the STPI project proposal, the idea was to conduct research that would have direct impact on S&T policymaking and decision-making in industry. STPI's initiators were anxious to belie the widespread criticism that researchers produce interesting but useless reports in science and technology policy. For this reason both the participants in the Barbados meeting and the sponsoring agencies emphasized the action-oriented approach of STPI. The first steps in organizing the country teams, identifying the host institution, and setting the research in motion underlined the implications of action-oriented research. Still, some teams decided on an academic rather than an action-oriented research approach.

Action-oriented research in the field of science and technology policy requires first a dual commitment, both to research (to advancing the state of knowledge) and to action (providing advice to policy- and decision-makers). A dual commitment, in turn, requires the ability to maintain a delicate balance. For example, having access to information may compromise the freedom to publish research results. Researchers may be obliged to uphold the official views of an agency providing information even when their values and ideologies conflict. At times, researchers supporting the objectives of particular agencies may exercise self-censorship to avoid damaging their credibility and effectiveness.

The Dangers

The conduct of action-oriented research is fraught with possibilities of losing the balance.

A first danger is confusing action-oriented research with "service" projects; in the latter no commitment to advancing the state of knowledge is implied and the task consists of giving advice based on existing knowledge. One type of service project is the simple collection of data to justify decisions made in advance.

A second danger is to concentrate only on a particular problem, with the aim of explaining and predicting behaviour. This may be done through either developing theories or gathering empirical data without directing the outcome to the policy- and decision-making processes.

A third danger, which is the most difficult to avoid once the idea of providing advice is accepted, is to overemphasize action within the existing political framework. The expedient or practical approach should not preclude the search outside the existing framework for new ideas and solutions that could provide better answers to the problems at hand but that would require the policy- and decision-makers to deviate from their normal course. If no scope for change is seen by the researchers, the work and its results may be directed to groups challenging the existing framework, with the action orientation turning into "counter research" or "advocacy research."

The dangers in action-oriented research can only be dealt with by the individuals and research teams; they are outside the control of a central coordinating body. For this reason, the country teams in STPI needed to be autonomous, their members facing the issues and resolving them in what they considered the best way possible.

In one country, the STPI team believed that linking to policymakers within the existing framework would not lead to improved decision-making in science and technology policies; nevertheless, as soon as the reports and documents resulting from the research were released, they were delivered to the appropriate government agencies and policymakers.

In another country, one of the top government economic planners joined the team as a consultant and participated in all the deliberations of the team while the research was in progress. The flow of information allowed the introduction of new concepts and ideas into government economic policy long before any reports were made available.

In both countries, the teams were in academic institutions. Other teams, located in government organizations, did not have the problem of linking up formally with government organizations and policymakers. However, the degree of their integration into the decision- and policymaking processes was quite varied, showing that locating a team in government does not guarantee success.

Gap Between Theory and Practice

Action-oriented research should not be reduced to simple units for investigation. The entire picture needs to be viewed simultaneously. Thus, the STPI teams did not concentrate on only one aspect of the process of formulating and implementing science and technology policies but attempted to bridge the conceptual and practical gap between the process of formulating government policy and the behaviour of individual agencies or productive units. The methodological problems encountered should not be underestimated; however, each team dealt with them more or less successfully. The methods guidelines furnished a starting point for systematically handling this complexity and were expanded by the teams to suit their needs.

Another characteristic of action-oriented research is that it must be contextual, reflecting the history and present situation. STPI research was placed in context by the use of the implicit policies concept and the adoption of an historical perspective.

In the field of policy design and implementation, action-oriented research must focus on the interrelations between policy formulation and individual decision-making. Policies are formulated by government (macro level) to guide and orient specific actions by agencies, institutions, and enterprises (micro level). The link between policymaking and action, however, is not usually considered. This is true even though the link can be a deciding factor in individual decisions at the micro level, which determine the way in which the country's S&T capabilities develop. Therefore, perhaps the key task in STPI research was to determine how policies filter down through the government machinery and condition individual decisions — in other words, the way in which policy instruments mediate between policies and actions.

Clearly, talking about two levels — the macro and the micro — is a simplification. In fact, there are several levels of policy formation and decision-taking, and, at each, investigators must examine the nature of conflicts between individual and collective reasoning. This task requires a basic understanding of the driving forces and motivations of the actors at all levels and is only mildly aided by formal concepts. Nevertheless, concepts such as “policy instruments” and “cluster of policy instruments” helped to focus the research of STPI on the interrelation between policies and decisions on S&T activities.

Some teams chose to follow the methodological guidelines in an orthodox way, went as far as they could go, and then developed their own set of concepts, borrowing in most cases from other developments in the literature. Some teams concentrated on a specific problem within S&T functions; they modified the guidelines early, finding that the concepts in the guidelines were too general. However, in all cases the aim of examining the interrelations between policy and decision was maintained.

Another characteristic of action-oriented research is that the researchers' value systems also influence investigations. Within STPI, there was an array of ideologies and values held by the participants in the network, and there was no use ignoring the differences. However, there were no major conflicts possibly because there was greater homogeneity of views than initially anticipated but more likely because of the way in which the STPI project was designed and organized.

Values in Research

Although the participants in the STPI network held different political views with regard to the future of their own countries and the development model that should be followed, they held a similar view of the policies needed for applying science and technology to development objectives. Agreement was easily reached on the objectives and approach of the STPI project as contained in the original STPI project proposal. In addition, the autonomy of the country teams and the agreement to exchange information prevented any conflicts that might have emerged from one group's trying to impose its views on others. In fact, there was

good ground for mutual understanding, and the ideological conflicts were not as acute as anticipated.

Attempts were made by some teams to define their values explicitly. One of the teams outlined a desired model of society, providing a norm for the redesign of science and technology policy instruments. A second team chose to work within the framework established by the government but sought to reorient the treatment of science and technology in the context of the 5 year economic development plan. Another team decided to focus efforts on defining government policy and policy instruments for particular industrial branches, where change seemed to be more realistic.

The operational characteristics of action-oriented research are primarily organizational requirements. For example, the research must produce knowledge and results in time to be useful for policy- and decision-makers. The research timetable is particularly important if the results are to be provided to users as the research proceeds. In the STPI project, timing

was not a major problem, because most of the teams did not interact with policy- and decision-makers on a day-to-day basis. In one case, the country coordinator became a top policymaker in industrial science and technology policy and altered the timing and content of one part of the research to provide information on the institution he was managing. Changes in government policy also modified the timing and content of the research, and in one case a new director of a science and technology agency demanded results for a national congress on science and technology.

Another organizational requirement of action-oriented research is to involve the "actors." Ideally, the researchers, policymakers, and decision-makers engage in a collective search for solutions, without impositions by any party. In STPI, very few of the teams reached the ideal. Only one team secured participation from consultants and government officials. Most other teams exposed decision- and policymakers to partial results but did not involve them in the research activities.

Chapter 2

The STPI Countries

The growth of industry and the evolution of science and technology in the STPI countries along with the specific conditions of underdevelopment provide the backdrop for the development of scientific and technological capabilities. In this chapter, the emphasis has been placed on identifying common features and on deriving implications from the comparison of national situations. The specificity of the national studies, however, and the heterogeneity of research approaches of the country teams limit the comparability of findings. Consequently, the generalizations of this and subsequent chapters should be considered as working hypotheses requiring further study and development.

Common Features in Industrialization

Much industrial growth among STPI countries was due to import substitution, which was introduced first by Argentina, Brazil, and Mexico after the Great Depression of 1929, and later (in the 1950s) by the other Latin American countries (Colombia, Venezuela, and Peru) as well as Egypt.³ Initially, import substitution was an attempt to deal with crisis shortages of manufactured products in international markets or with contractions in the markets for primary commodities that were a country's source of foreign exchange to pay for imports. Because the growth of industry was conditioned by the imports of intermediate and capital goods, any crisis in the balance of payments immediately turned into a crisis for industry. Import substitution industrialization started as a response.

South Korea combined import substitution

with the production of goods for export to the Western industrialized nations, emphasizing the latter both with respect to total output and investment. As a consequence, South Korean industry is highly vulnerable to changes in the international market as well as to economic recessions in countries that supply South Korea with industrial inputs and absorb its products.

The present industrialization drive in Korea began after a devastating war, concurrently with the reconstruction efforts financed by the U.S.A. In the middle 1950s the problem was not one of substituting imports, for they had been limited by the war, but rather of preventing new imports from flooding the domestic market. In this sense, protection of the domestic market had a different character than in Latin America.

Like South Korea, the Socialist Republic of Macedonia was involved in war just before moving toward industrialization. However, it represents a special case on several accounts. First, it is a republic of Yugoslavia; second, its productive, financial, and trading systems have been controlled by the state and by a self-managed economic system; and third, it occupies a special position between Eastern and Western Europe. The pattern of industrialization has been influenced by all these factors, and particularly by the state control of the economy during the reconstruction period after World War II. Collective control, self-management, and government planning — still in force though much weakened by several reforms (1965, 1971, 1974) — have also shaped industry. The Macedonian industrial structure, similar to the Yugoslavian one, rests on the heavy industry that was established with the assistance of foreign technology imports.

The consumer industry branches in Macedonia were not expanded early enough to support industrial growth, and since 1965 foreign loans, imported technology, and joint

³ Because no material was made available, India has been excluded from the analysis.

ventures and collaboration agreements with foreign enterprises have been the mainstay of industry. As a result, industry has been unable to absorb the expanding labour force, and there are serious unemployment and migration problems.

Import Substitution Industrialization

Import substitution industrialization found in the Latin American countries and in Egypt began as a result of world crises. The 1930s depression and the Second World War led to deficits in the trade and payments balances so that countries needed to save foreign currency by reducing imports. Moreover, the two events restricted the supply of products manufactured by the Western industrialized countries⁴ and stimulated investment in local industry to satisfy the social strata with purchasing power. In other words, the main components of import substitution industrialization were deficits in the balances of trade and payments, the availability of finance for local investment, and the existence of a social class with the means for increasing and diversifying its consumption.

In general terms, import substitution has two stages: first, substituting consumer and some light durable goods and, later, intermediate, basic, and capital goods. Not all the countries under consideration have managed to make a smooth transition from the first to the second stage, and their industrial development shows the strain. The countries that proceeded to the second stage early (Argentina, Brazil, and Mexico) encountered less difficulties than Colombia, Egypt, Peru, and Venezuela because they had larger internal markets to support their industrial structures and a greater industrial base at the time import substitution was initiated.

Before import substitution began, local industry was rudimentary, producing low-cost consumer goods. It was profitable because the high costs of transport provided natural protection from import competition. In some countries, such as Brazil, during the first 3 decades of the present century, local industry produced an incipient mass market for

industrial products. The technological requirements of industrial production were low, and quality did not matter. Obsolete machinery and equipment could be imported at a relatively low cost as it was discarded in the more advanced countries (which were expanding their industry very rapidly). In general, the governments levied no duties on imports of machinery. Argentina was an exception, imposing duties on imports of capital goods up to the 1930s. (Brazil levied tariffs on some capital goods imported in the 1930s). In Argentina, throughout the early phases of import substitution, prices of capital goods were high compared to consumer goods, making the process of capital formation in industries very difficult.

In Argentina, Brazil, and Mexico, the mechanisms utilized by the state to support and protect existing manufacturing provided the framework for capital accumulation and subsequent expansion of the light industry sector.

During the early phases of industrialization, the primary sector — agricultural activities in particular — supported industrial growth in a variety of ways. Agricultural activities supplied low-cost food to the urban centres and raw materials that were transformed by industry. The migration of rural workers to industrial centres generated a pool of jobless people and allowed wages to be kept down. For example, in Mexico, the elimination of traditional landholding patterns that tied the rural worker to the land and the elimination of internal duties, which impeded the flow of agricultural products, led to a flow of peasants to the urban areas in the 1920s and 1930s, an abundant source of cheap labour for industry. Agricultural exports also generated the foreign exchange to import the capital goods and material inputs required for industrial activities. Finally, through unfavourable terms of trade between rural and urban production, there was a net transfer of resources toward urban manufacturing that helped in the process of industrial accumulation.

Today, agricultural activities continue to support industry in most STPI countries. In Argentina, agriculture and cattle raising still generate the foreign exchange required to import capital goods and industrial inputs. In Colombia and Brazil, coffee exports are the main sources of foreign exchange. In Peru and Egypt, manufactured products continue to benefit from trade despite some measures to protect agriculture. Since World War II, how-

⁴ To a certain extent, Venezuela was an exception to this because of the privileged and strategic character of its oil exports.

ever, agricultural activities have stagnated and are no longer able to support industrialization in the same way as previously.

In some countries, other exports generated foreign exchange for industry, i.e., oil in Venezuela, minerals and fishmeal in Peru, whereas agriculture has been the source of displaced labour, resource transfers, raw materials, and food. Thus the general picture that emerges during the first stage of import substitution industrialization is one of industry eliciting support from primary activities for its expansion and receiving political support from government. During this phase, the countries under study began to attract foreign investors, and many industrial activities came under foreign control — a situation that still obtains for the smaller STPI countries following the import substitution road to industrialization (Colombia, Perú, Venezuela, Egypt).

The 1930s

In the economic crisis of the 1930s foreign markets could not absorb all the exports of primary commodities; the monetary chaos reduced sharply the flow of foreign investment. This meant that capital would have to come from internal sources, such as the primary sector and the state. New institutions were created to take charge of fiscal, monetary, and credit policies (central banks, development financing corporations) and to manage new policies regulating the flow of imports, etc. At the same time, measures were taken to expand higher education and to create an incipient scientific and technological infrastructure. In Mexico, the oil industry was nationalized and in the large countries the role of the state in orienting economic growth began to expand.

The interests of the state and those of private industry coincided to a large extent during this period, and government policies promoted the selective distribution of credit to bolster local industry. Monetary policies alternately benefited local entrepreneurs and foreign investors (stable exchange rate periods followed by devaluations); imports and exports were taxed selectively to eliminate foreign competition and to sustain the income of local exporters of primary commodities generating the necessary foreign exchange. In some cases, as in Mexico, tariffs were instituted as a way of generating income

for the state, in addition to providing industrial protection.

The policy instruments introduced in the 1930s were kept in force throughout the Second World War, and production continued to be directed toward the export of primary commodities. A local market emerged, and imports were primarily capital and intermediate goods, which were absorbed by the productive system. Some consumer goods were also imported in relatively small quantities (and taxed highly) for the benefit of the high-income minorities; the needs of the majority of the population were satisfied, although not fully, with locally produced goods: foodstuffs, household goods, textiles, footwear, building materials, and other light durables.

As the economies expanded, the state became more involved, undertaking unprofitable but essential investments, such as the provision of energy, transport, and other basic services. State intervention in these activities was not always a willing and planned undertaking; in Brazil, for example, the state could be considered a reluctant entrepreneur in taking over electricity generation and steelmaking. The state was less reticent in oil production and refining, particularly in Mexico and Brazil, where it acted against foreign enterprises, which had a virtual monopoly. The pattern of state involvement was the same for all the STPI countries. In the case of Egypt, state-owned enterprises accounted for a very high percentage of industrial production, reaching 75% in the late 1960s.

During and preceding World War II, international demand for raw materials and primary commodities was at a high. The countries under survey were able to accumulate foreign exchange but due to shortages of foreign supplies were forced to cut back imports. The combined effect was increased public expenditures, expansion of industry (including the use of existing idle capacity), and growth of the domestic market, particularly in urban areas.

The economic booms were followed by economic crises in all the STPI countries involved in import substitution. One of the problems was the depletion of foreign reserves; it was compounded by the shortage of foreign capital, which was channeled mainly to the reconstruction of the European and Japanese economies. Also, the first impulse toward import substitution industrializa-

tion was reaching its limits. The substitution of consumer goods and light durables was constrained by the narrowness of domestic markets; and agriculture was stagnating, not able to provide support to the same degree as in the early stages. Foreign exchange shortages resulted from the inability to sustain exports; the accumulation of capital within the industrial sector had not reached the proportions required for a self-sustained expansion of industry; and the transfer of financial resources from the industrialized centres was not forthcoming. The crises were felt first in the larger countries (late 1950s and early 60s) accompanied by deep monetary instability, inflation, and unequal balance of payments, which led to devaluations, debt rescheduling, and, toward the end of this period, to a new inflow of foreign capital through loans and direct investment, channeled mainly to manufacturing industry.

During the crises, the countries moved toward the second stage of import substitution in a gradual way; the transition was shaped by the measures taken to overcome the crises. New legislation was introduced to restructure industrial protection and promote the expansion of intermediate and capital goods industries. Import licences and quotas were introduced; tax rebates and other fiscal benefits for industry were put into effect; special regimes were designed for selected industries; and government agencies were reinforced or created to provide credit facilities for industrial expansion. This array of protectionist policy instruments helped to promote the growth of industry and motivated the import of capital goods, intermediate products, and of technology, which together began to account for about three-quarters of the total import bill. The result was incompressibility or rigidity in the structure of imports; any reduction in the volume of imports was bound to affect not only final consumption but also industrial production, curbing significantly the activity of some industrial branches. In turn, the incompressibility of imports led, in the face of uncertain foreign exchange earnings, to greater indebtedness.

Furthermore, the tariffs and administrative controls associated with protectionist policies had a differential impact on the growth of various industrial branches. Toward the end of the first stage and, to a lesser degree, during the second stage of import substitution, goods for final consumption were protected more

heavily than intermediate or capital goods. Thus, the incipient capital goods industry faced competition from foreign machinery and equipment that was imported at low duties and was subject to limited controls. The competition, along with the small size of the internal market and the difficulties in acquiring and assimilating technology, limited the growth of the capital goods industry.

Despite some problems, the growth of the capital goods industry was promoted by state intervention. State enterprises intervened in articulating a demand for locally produced machinery and equipment in Brazil and Argentina, imposed tariffs for certain capital goods that could be manufactured locally, and introduced supportive policies. For example, Colombian regulations that forced depreciation of machinery and equipment in 10 years stimulated repair and maintenance activities and created a market for used and reconstructed machinery. When incentives were given to the metal-working industry, the existing capacity to repair and reconstruct equipment — primarily associated with the large enterprises (mainly textile mills) — was instrumental in the transition toward the manufacture of some capital goods, and repair shops were converted into metal-working firms.

Protection: Boon or Bane

Protectionist policies helped to turn manufacturing industries — particularly consumer goods industries — into profitable ventures (capital was supplied at low cost, industrial inputs were subsidized, fiscal incentives were provided, and so on). Local entrepreneurs operated in an easy environment and did not develop cost consciousness, technological inventiveness, or risk-taking ventures.

As well, protectionist policies attracted tariff-jumping foreign investment to exploit the local market; combined with measures to stimulate the inflow of foreign capital and the renewed availability of international capital, they led to a new wave of foreign investment in STPI countries. By the end of the 1950s and the beginning of the 1960s, foreign capital dominated the most profitable industrial branches, through direct investment, purchases of already established firms, joint-venture agreements, or public and private loans. Foreign investment was

designed to establish new lines of production or to modernize old ones, tying the inflow of capital to the supply of technology in the form of machinery and equipment, intermediate products, technical assistance, licencing agreements, etc. Multinational firms were at the forefront, providing foreign capital and serving as channels for technology transfer. Due to the economic conditions prevailing in the recipient countries, their weak industrial structure, and the limited size of the domestic market, the foreign firms operated from the state as monopolies or oligopolies.

In taking advantage of the market, foreign firms were chiefly responsible for introducing technical change in the newly established industrial branches. They brought technologies from abroad, introducing few adaptations to meet local conditions. Large-scale capital-intensive techniques of production were employed in the branches that attracted foreign capital, and the new technologies raised productivity without significantly bolstering industrial employment levels.

The Domestic Market

Throughout import substitution industrialization the narrowness and composition of the domestic market has limited the growth of industry. Although there was a moderate enlargement of the domestic market with the expansion of the urban population, the import substitution industries catered mainly to the high-income strata of the population. Inequalities in income distribution prevented the emergence of a mass market for manufactured goods even in countries, such as Brazil, with large populations. Furthermore, the narrowness of the domestic market, coupled to investments in large-scale plants, led to the widespread underuse of installed capacity.

The predominance of agricultural and artisan activities, which are not fully integrated into the market economy, and the existence of large sectors of the population engaged in marginal service activities in urban areas (Mexico, Brazil, Egypt) limit the purchasing power of the majority of the population, preventing them from joining the market for industrial goods. This situation has been aggravated by the fact that industry has been unable to generate adequate employment opportunities to absorb the increasing labour

force. As a result, the domestic markets for industrial products have remained small in comparison with the potential based on full participation of the populations.

The inability of agriculture or industry to finance industrial expansion has meant a massive inflow of foreign finance. The result has been heavy foreign indebtedness and high payments for interest and amortization. An increasing share of foreign exchange earnings have been devoted to the external debt instead of purchases of intermediate products and capital goods for industry. In some countries, like Perú and Egypt, foreign exchange availability for industry has been further reduced by the amount that is devoted to food imports.

Recent attempts to sustain the drive toward industrialization in the STPI countries following the import substitution road include, among others, the promotion of manufactured exports in the industrialized economies (Argentina, Brazil, Mexico), the expansion of domestic markets through regional agreements (Colombia, Perú, and Venezuela as members of the Andean Common Market), redistribution of income (Perú), encouragement of foreign investment (Egypt), and increased exports of primary commodities (oil in Venezuela and minerals in Perú). In all cases, the efforts toward building a more coherent industrial structure progressed, and the importance of building up a local base of industrial technology began to be recognized.

South Korean Strategy

South Korea is the only country in the STPI network that has developed an industrial structure oriented primarily toward export of manufactured goods. In contrast with the countries examined previously, South Korea does not derive most of its foreign exchange from exports of primary commodities. Rather, it exports manufactures for which low wages provide a competitive edge.

Industrialization in South Korea was preceded by post-war reconstruction in the 1960s, carried out with large-scale financial assistance from the USA. At the same time, the educational system was expanded, and a large number of South Korean professionals were sent abroad for postgraduate studies. During this period, a minimum governmental

infrastructure was created and consolidated.

After reconstruction, industrialization began with the production of consumer goods and light durables through a process of import substitution, but government measures were directed to preventing imports into the South Korean domestic market rather than to promoting their substitution. Previously, imports had been drastically reduced because of war, and before that, during the Japanese occupation they had been rather limited. This import substitution component of South Korean industrialization has remained in force even throughout the period of export-oriented industrialization, which began in the 1960s and continues today.

After the 1950-53 war, the redistribution of land accompanied the beginnings of industry. For 2 decades trade between rural and urban areas favoured the latter although this was offset by subsidies to farmers and by food aid from the USA. More determined attempts to correct this imbalance have been made in the 1970s. Rural areas also provided displaced labour to industrial and service activities. Lacking natural resources and cultivable land, South Korea has exported negligible primary commodities. Efforts have turned instead to reaching an acceptable level of self-sufficiency in food supply.

Starting in 1961, the government intervened actively in shaping the industrial structure and began to interact with private interests, primarily the exporters of manufactured goods. As a result, the majority of government measures were directed toward supporting the exports of manufacturers and ensuring the profitability of firms exporting a substantial part of their output. Direct government intervention in productive activities has been limited to providing the necessary infrastructure for industrial growth and to initiating ventures in areas too risky for private entrepreneurs. The close link between private entrepreneurs and government officials provides a framework for putting into effect government plans and for ensuring state support to private industry.

Because of its industrialization strategy, South Korea has become highly vulnerable to changes in the international market. Given that the bulk of its manufactured exports go to the United States of America and Japan, any downturn in their economies immediately translates into reductions of exports. Furthermore, the lack of natural resources

makes South Korean industry highly vulnerable to fluctuations in supply and price levels, as was shown by the rise in oil prices in 1973-74. Although foreign exchange represents a rather high percentage of the Gross Domestic Product, it has not been sufficient to sustain South Korean industrialization. Japanese and American investments in key branches of industry, suppliers of credit for capital goods, and foreign loans guaranteed by the government have supported South Korean industrialization.

In contrast with other countries following the export promotion route to industrialization (Singapore, Taiwan, Hong Kong), South Korea has a rather large potential domestic market, which could absorb more output, should industry be oriented from exports toward local consumption. There may in fact be a trend in this direction as inequalities in income distribution have been diminishing in the 1970s and measures have been taken to correct the rural-urban imbalances, keep peasants in rural areas, and eliminate the bias toward industrial and service activities that drain resources from the labour force engaged in agriculture.

The relatively high level of technical skills and education of the South Korean labour force has been of great importance in supporting the drive toward industrialization. The investments in education of the 1950s and early 1960s paid off for industry at least. The high educational level of the population and the low level of wages provided South Korean industry with trained, low-cost labour and a means to compete successfully in the international market. However, the rising levels of per capita income and the measures taken in the mid-1970s to lessen inequalities will divest industry of its labour costs advantage. Anticipating this, the government officials are now talking about switching from labour intensive to "brain intensive" industries, increasing the technical and professional level of its labour force and industry to compete in the international market during the 1980s.

Mixed Industrialization in Macedonia

Macedonia is unique in the context of the STPI project: it is a republic of Yugoslavia, it has occupied a singular position between East and West Europe, and it has planned and managed its economy. After World War II,

Yugoslavia (and Macedonia as part of it) was engaged in reconstruction with the assistance of the Soviet Union. The reconstruction period was characterized by a planned approach to industrial development that emphasized import substitution and the growth of basic and heavy industries in the socialist manner. At later stages, when the ties with Eastern Europe were loosened and regional autonomy increased, an employment generation component was added to the industrialization strategy of Yugoslavia. The strategy was complemented later by efforts to find a place within the international division of labour of the industrialized market economies, primarily by fostering exports of manufactured goods. The country sought joint-ventures with Western enterprises, imported large amounts of capital goods, and attempted to upgrade its technology. Thus, Yugoslavia in general, and the Republic of Macedonia in particular, followed an industrialization strategy that combined a variety of components.

Industrial growth in Macedonia has been, and still is, supported by resource transfers from the agricultural sector. Imbalances in the terms of trade between rural and urban areas have led to the net transfer of capital from the former to the latter, and agricultural activities have been a source of industrial labour. Furthermore, agricultural exports have provided some foreign exchange.

State intervention has been dominant throughout industrialization in Macedonia. Protectionist measures fostered the growth of basic industries first and consumer goods and light durables later. Throughout the 1950s, a variety of government-controlled sources of financing provided capital for industrial expansion, and after 1965, the measures introduced to promote exports led to the establishment of new industries. Constitutional reforms have weakened the role of the federal and republican governments and have given more autonomy to the self-managed enterprises, although government intervention is still present in industrial activities.

Yugoslavia switched from the division of labour within the socialist sphere of influence to the division of labour among Western market economies but retained ties with both camps. The switch gave a peculiar character to the influence of the external sector on Yugoslavian and Macedonian industrialization.

Joint-venture and commercialization agreements with Western enterprises have allowed industry to obtain financing and technology and to find export outlets in the West, generating foreign exchange. The access to Western technology and the trading agreements with Eastern European countries have provided new market opportunities that are not open to the same degree to Western economies.

However, the narrowness of the domestic market and the regional disparities in the Yugoslav federation have been a barrier to industrial expansion in Macedonia. Unemployment and migration, which are related both to the relative stagnation of agriculture and to the inability of industry to absorb an expanding labour force, limit the possible expansion of industrial activities.

Common Features

Despite the differences arising from specific historical conditions, size of the market, resource endowments, characteristics of the population, and other contextual factors, there are similarities in industrialization in the STPI countries.

First, in none of the STPI countries, has modern industry developed as a result of the gradual transformation of local crafts and artisan activities. Rather, it resulted from transplants of productive facilities and of technology from countries that had achieved a higher degree of industrialization. Imports of machinery and equipment, migration of skilled personnel, purchases of technology and foreign technical assistance have been at the centre of modern industrial growth in the STPI countries, whereas local invention, innovation, and even adaptation of foreign technologies have played a minor role. Thus, industrial development has been strongly conditioned by the possibility of acquiring and absorbing foreign technology.

Second, in all STPI countries agriculture has provided the initial accumulation base for industry and has supported industrialization in a variety of ways. Only in South Korea was the agricultural input minor. In some countries in the STPI network, mineral exports also provided limited support to industrialization, particularly through the generation of foreign exchange to finance industrial inputs. In most countries, the transfer of resources from the primary (mainly agricultural) sector to the

industrial sector still continues, and industry has not been able to generate the surplus and the foreign exchange necessary to sustain its own expansion. As a result, the relative stagnation of agriculture and the fluctuations in the international commodity markets have had a disturbing effect on the growth of industry.

Third, the state has been of paramount importance in shaping industrial development in the STPI countries. When deliberate industrialization efforts began, protectionism played a key role in stimulating local production, particularly in the countries that followed the import substitution road. Protectionist measures have had a mixed impact on industrial growth and on the development of technological capabilities, but it is hard to see how local industry could have developed in any other way during the initial stages. Even the countries that have followed an export-oriented (South Korea) or planned (Macedonia) approach to industrialization have included import substitution components in their industrialization strategy. Protectionist measures taken by government and maintained for long periods have created a relatively facile environment for local entrepreneurs and have stimulated the inflow of foreign investment to take advantage of the local market.

The large number of government measures and the variety of contexts that mediate their effects have created in all STPI countries a complex web of interactions. The impact of a single government measure is difficult to assess, as is the real influence of policy instruments. Active government intervention in productive activities through state enterprises adds another dimension to the problem. In this regard, key issues are the coincidence and interpenetration of interests between the state and industrial entrepreneurs and the extent to which the state is prepared to support industrialization.

Fourth, all the STPI countries are open economies in the sense of depending, in some way or other, on the external sector for industrial growth. Those that relied entirely on import substitution continue to depend on the export of primary commodities to generate foreign exchange for importing industrial inputs. South Korea is highly dependent on foreign markets for the export of its manufactured goods (primarily consumer and light durables), and particularly on the

channels that place its products in the USA and Japan. Most of the STPI countries are also dependent on imports of oil (with the exception of Venezuela and Mexico), and all of them have required large transfers of financial resources to support their industrialization drives. All have incurred heavy foreign debts. Even Venezuela, with its surplus of foreign exchange generated by oil revenues, has been unable to substitute the imports of foreign capital, which come tied to technology, productive facilities, and several other services required to materialize industrial investments.

Finally, the narrowness of the domestic market for industrial products in most STPI countries has limited the growth of industry and has been closely related to unequal income distribution, with large segments of the population remaining at the margin of economic life. Industry has not been able to absorb the expanding labour force, and industrial employment cannot be counted on as a means for expanding the domestic market. However, in South Korea, which has a large population, rising incomes, and more balanced income distribution, the potential domestic market could absorb industrial output in the near future if necessary to offset export difficulties.

The common features of industrialization indicate that the STPI countries have not generated enough demand to stimulate the growth of domestic scientific and technological capabilities. The appearance of modern industry as a transplant from Western industrialized countries instead of an outgrowth of local crafts; the inability of industry to finance its own expansion and the reliance on primary activities to sustain it; the ambiguous environment provided by protectionist policies; the lack in most cases of a clear technological development plan on the part of government (with the recent exceptions of India, Brazil, and South Korea); the reliance on foreign technology; and the structure of the domestic market combined in all the countries to make industry dependent on foreign sources and to limit the demand for local scientific and technological activities.

Science and Technology

Three strands can be discerned in the development of Western science and technology — the emergence and growth of

scientific activity, generating organized knowledge to understand and control physical, biological, and social phenomena; the evolution of modern productive techniques, slowly at first and then explosively as science-related technology emerged; and the relative stagnation (and frequently, disappearance) of traditional crafts. The last strand is of particular importance in the countries that did not participate actively in the scientific and technological revolution. For them, the traditional non-Western technological base was, and still is, of great importance for productive activities. They would likely benefit from a study of the traditional crafts, artisan work, or subsistence productive activities that are displaced by the last strand of S&T development; however, such study was not considered within the scope of STPI research.

In a few countries, science merged with technology toward the second half of the 19th century (e.g., Western Europe and, later, Japan and the USA), and a veritable scientific and technologic revolution took place, led to the generation and spread of technologies, eventually resulting in a solid endogenous scientific and technological base. In STPI countries, the symbiosis between science and production technology did not take place. Instead, they imported the technology required for modern industrial activities, and they now have an exogenous scientific and technological base, which is not designed for their specific conditions and characteristics. Furthermore, because of their rather low level of scientific and technological development, they have not been capable of providing the knowledge required for maintaining, replacing, or improving the imported technological base and have been forced to rely continuously on foreign inputs.

Before Western Europeans imposed their culture on the peoples of Latin America, the Middle East, India, and Southeast Asia, the indigenous technology had reached a rather high level relative to the social, economic, and political situation. Through a slow process of trial and error, the traditional technological base had been gradually improved. In some areas, notably India and Central America (the Mayas), speculative thought had also developed but was far from being combined with the advancement of productive techniques.

The Spanish conquest during the 16th century disrupted the traditional organization of productive activities in Latin America. After a short period of acculturation, during which the newly arrived Europeans learned to operate in an alien environment, a systematic displacement of traditional ways of doing things took place, accompanied by religious intolerance, which put an end to indigenous speculative thought. The arrival of the British in India was slightly different primarily because it happened nearly 2 centuries later, when the industrial revolution had produced its first fruits. Scientific and engineering advancements were used to determine the best way of exploiting the Indian subcontinent, and British products were introduced, smothering traditional crafts and ancient modes of thinking. In the Middle East, the arrival of the French and the British hastened the decline of Islamic civilization which had begun to decay after the Ottoman conquest. In contrast, South Korea remained isolated from the influence of the West until the end of the 19th century.

The subsequent evolution of science and technology in the colonies was tied to the conditions prevailing in the colonial powers. Spain and Portugal remained isolated from the scientific advances in Europe during the 17th century, the crucial period for the emergence of Western science, and their colonies in Latin America also were at the margin of the new currents of thought. Not until the last third of the 18th century, when the Enlightenment reached the Iberian peninsula, did new ideas begin to filter down to Latin America. Shortly thereafter, as a result of the wars of independence during the first 2 decades of the 18th century and the political and economic instability until the 1850s, much intellectual ground was lost, and it would take another half-century for the establishment of an incipient scientific community in Latin America. This new beginning for science in Latin America was closely associated with the spread of positivism, which had an impact on education, politics, and social organization in general.

In India, the United Kingdom's economic interest spurred a variety of scientific activities, ranging from geologic and geodesic surveys to the study of indigenous plants. Indians were excluded systematically from the activities, and Indian science took a definite colonial flavour: it was performed by British scientists and put at the service of the Empire.

Nevertheless, at the turn of the 20th century, there were several nuclei of scientific activity throughout the subcontinent and an incipient Indian scientific community.

In Egypt, after the arrival of Napoleon, who sponsored the creation of the "Institut d'Egypte", Muhammad Ali focused efforts on transforming Islamic culture and absorbing and adapting the advances of Western science. After his demise, his reforms soon lapsed into oblivion, and by the end of the 19th century there was almost nothing left to show his modernization efforts.

The colonial expansion of Western Europe and the consequent spread of new industrial technologies led to a disappearance of many traditional crafts. Often modern and traditional technologies intermingled, with the latter sustaining the marginal economic activities. When modern industrial activities began to grow during the late 19th century and the beginning of the 20th century, the technology to sustain them was imported because the indigenous scientific and technological infrastructure had not been developed sufficiently. Thus, the conduct of science and the performance of modern productive activities were divorced early in industrialization, and there was never even a marriage between Western science and the traditional technological base in the colonies.

When the drive toward industrialization started in the STPI countries at the beginning of the 20th century, science had not developed into a well-established activity. It did not enjoy the steady support of government institutions and had not made any significant contributions to world knowledge or to local productive activities. There was no social demand for science because of the incipient level of economic development; the predominance of imported Western productive techniques; the existence of values and attitudes that did not foster the pursuit of science; social and political instability, which precluded the growth of an indigenous scientific tradition; and the lack of cultural identity that could absorb and fully integrate Western science.

Science and technology in the STPI countries during the 20th century followed a more regular path and was tied more closely to industry. Industrialization created a demand for scientific and technological activities, particularly those of an applied and service nature. For example, the engineering

profession emerged as a result of pressures exerted by infrastructure development (railroads, ports, roads) and mining, manufacturing, and some modern agricultural activities.

The technical difficulties at different stages of import substitution industrialization in Latin America conditioned the growth of industrial science and technology activities. Technical norms and standards institutions were created first to put order into the chaos resulting from importing machinery and equipment from various European countries and the USA. Then centres to increase and rationalize productivity were created to offset sagging demand, overcapacity, and the inability to substitute more complex products. Technological research institutes appeared on the scene about the same time as productivity centres, particularly in the countries that had gone furthest in substituting imports of intermediate and capital goods. Although Egypt was behind Latin America in the import substitution process, the emergence of industrial science and technology activities followed a similar pattern.

In India, the two world wars stimulated the development of industrial scientific and technological activities, although it was not until World War II that a network of industrial research institutes was set up. In South Korea, whatever S&T facilities existed were destroyed during the 1950-53 war and had to be reconstructed. The same can be said of the Republic of Macedonia, which was engaged in reconstruction after the Second World War.

Even though scientific and technological activities in STPI countries were more in line with industrial growth during the 20th century, in no way did they become a significant source of innovations for industrial growth: STPI countries continued depending on imports of technology from the industrialized nations. The scientific and technological base lagged behind the requirements of modern industry and could not provide industry with the steady flow of technical knowledge necessary to improve efficiency and maintain competitiveness.

Only recently has this situation changed. Argentina, Brazil, India, and Mexico, which began their industrialization earlier than the other STPI countries, have absorbed and complemented imported technologies in some areas of industrial activity and have begun exporting them to developing

countries with a lower level of industrialization.

The STPI countries have several S&T features in common because the pursuit of science is strongly conditioned by the scientific centres of the advanced countries and because technologies for modern productive activities have been mostly imported from the industrialized nations. However, there are also some important differences among the STPI countries, resulting primarily from the degree of development of the local scientific community and the context for the performance of research and other scientific and technological activities.

Two different stages can be identified in the development of science and technology in the STPI countries, although there is no automatic transition from one to the other. In some of the STPI countries — Colombia, Perú, Venezuela, Egypt, and Macedonia — science and technology are still in the *formative stage* in the sense that they are just beginning to emerge as significant and recognized activities with an identity of their own. In the other countries — Brazil, Argentina, India, Mexico, and South Korea — science and technology are undergoing *consolidation* in the sense that they have reached a significant level of development, have acquired legitimacy, and are recognized, although not universally, as important social activities. The two categories are not clearly differentiated, but there are indicators, such as size of the scientific community and the qualified human resources base; degree of development of the institutional infrastructure and its internal coherence; legitimacy of the activities of scientists; results obtained from scientific research and other scientific and technological activities; and degree of development of industry and importance of the demand pressure exerted on the local scientific and technological community.

Modern science is relatively young in all STPI countries. There has not been sufficient time to develop a well-established scientific tradition and to disseminate through society the attitudes, points of view, and values associated with the conduct of scientific inquiry. The performance of scientific research in a systematic and continuous way did not begin until the 1st decades of the 20th century, and in the countries where science and technology are at the formative stage, a significant level of scientific activity emerged

only after World War II. Thus, science is still in its infancy in the STPI countries, and it is likely to take several decades of continuous growth before it can contribute significantly to development. But scientific inquiry in the industrialized world will continue to move ahead and will likely stay beyond the grasp of the STPI countries — with the possible exception of India — at least until the end of the 20th century.

The Formative Years for S&T

Countries whose science and technology are at the formative stage have stressed that S&T activities are on the margin of social and economic life. Marginality is a complex concept comprising features such as the limited size of the scientific community, the excessive fragmentation of the science and technology effort, the lack of correspondence between development aims and local science and technology, and the inability to incorporate the results of research activities into productive and social processes.

For example, in the mid-70s, Colombia, Perú, Venezuela, and Macedonia each had less than 1000 full-time researchers, most of whom were also involved in other activities, primarily teaching and advising. Funds allocated for scientific and technological activities were rather limited, representing around 0.2% of GNP, and, on average, fewer than 10 persons work in any given research institute in Perú, Venezuela, and Colombia. Figures for researchers, rather than total personnel, are on average less than five in these countries, and the average number of researchers per project was fewer than two. The average funds allocated in Venezuela and Peru amounted to about U.S. \$5000 per project in 1970, an indication of the research fragmentation.

The majority of research funds in the countries with science and technology at the formative stage have been directed toward basic research, with relatively smaller amounts left for applied research and development. (Even in the countries such as Perú, where researchers report to be doing mainly applied research, it was observed that the real applicability of research results was much lower than that reported by the researchers themselves.) A larger amount is spent on service and support activities and on educational activities related to science and

technology, but the proportion of funds and personnel allocated to research and service activities in the engineering and industrial fields has been very small in all the countries with science and technology at the formative stage. For example, in Colombia, Perú, and Venezuela, less than 10% of the total number of researchers were engaged in these fields and even a smaller proportion of research funds was allocated to them.

The consulting and engineering design activities are weak, indicating the difficulties involved in transferring research results to the productive sector. In Perú, for example, there are only 10 professionals per research centre, and they mostly consult on investments rather than engineering design. Rarely do research institutions provide consulting firms with their results to be incorporated into productive activities. Exceptions were found where government organizations intervened actively in promoting the use of research results, as in Colombia with its food and nutrition plan in the early 1970s.

In the countries where science and technology is undergoing consolidation, the isolation of scientific and technological communities and the lack of connection between science/technology and production are the major problem. There is a fine line separating the concepts of "isolation" and "marginality," although the former implies the existence of a relatively well-structured S&T community that is not integrated with productive and social activities, whereas the latter implies that the S&T community is not even structured in a coherent way on its own. For example, in Argentina, India, Brazil, Mexico, and Korea, the scientific and technological community is not marginal to the social and economic life; instead, it is not effectively utilized and is not linked with the productive sector. During consolidation, the coordination of research activities, their productivity, and the allocation of funds are major concerns. There are a relatively small number of very large institutions that dominate research activities, and the rest of the research activities are fragmented. Basic research predominates, but a variety of applied research activities, primarily of the adaptive type, emerge in the industrial sector. Many organizations perform research under contract from industrial firms, and attention focuses on solving a variety of problems specific to the country.

Whether the STPI countries have reached

the formative or the consolidation stage in science and technology, they all rely on imports as the main source of productive techniques for modern industry, partly because they have traditionally done so and partly because they can acquire foreign techniques faster, with guarantees, technical assistance, and complementary technical information. Furthermore, when they deal with transnational corporations or foreign financing, they often have no choice. However, in the STPI countries undergoing consolidation, there is some interaction between technology imports and the local research and engineering institutions, and many industrial firms have built up their own negotiation, information, and evaluation capabilities on alternative technology suppliers. As a result, they suffer less from the restrictions that usually accompany the imports of technology and pay less for the knowledge than do firms in countries where these capabilities have not been developed.

In STPI countries, the scientific and technological activities performed by industrial enterprises are relatively weak when compared with those performed by enterprises in the industrialized nations. Nevertheless, a substantial base of technological activities, primarily of the adaptive type, has been developed by industry in Argentina, Brazil, India, Mexico, and South Korea to assimilate and elaborate imported technology. Also during the last 2 decades, the STPI countries with a larger industrial base and with science and technology at the consolidation stage have been able to export technologically complex products and even to export technological services to other less-developed countries.

A common characteristic of all STPI countries is that very little contract research is undertaken. First of all, research organizations have not developed aggressive strategies to sell their services to industry, and industrial firms are seldom willing to pay for research or other technological services provided by local organizations. They are not familiar with the process of defining technical problems in a manner suitable for contract research, of monitoring the performance of the contractor, of evaluating the results, or of incorporating the results into their productive activities. In general, they have obtained information and other technical services as part of a package deal for technology imports or have gained access to them free from

government organizations.

Lack of scientific and technological support services and the weakness of higher education are also common to all STPI countries, but they are more acute in countries with science and technology at the formative stage. Argentina, Brazil, India, Mexico, and South Korea have a relatively larger number of higher education institutions and of professionals in engineering and scientific careers than do the smaller STPI countries. However, even in the first group of countries, there has not been a sustained and significant interaction between the technical higher education institutions and the productive sector.

Scientists and the State

In all STPI countries, scientists have shown a certain ambivalence with regards to state intervention in scientific and technological activities, and particularly in research. This ambivalence results, on the one hand, from their allegiance to the principle of total freedom of research and to the international character of science and, on the other, to the incipient stage of science development and the need to respond to local socioeconomic problems. This ambivalence is more manifest in the exact and natural sciences, in which scientists demand support from the government but are reluctant to accept any intervention in their activities. For example, the members of the mathematical and biological sciences committees of the Mexican science and technology plan publicly expressed their concern about possible government intervention, condemning it a year before the plan was completed. The statements of leaders from the Venezuelan association for the advancement of science show the change in attitude of the scientific community during the last 30 years — the move from doggedly opposing any state intervention to accepting broad directions for research derived from socioeconomic development priorities. The change has taken place partly as a result of the increasing intervention of the state in support of science and technology; for example, in Venezuela in 1970 more than 90% of all resources allocated to science and technology were provided by the state.

The predominance of the state in the financing, coordination, and even the performance of scientific and technological

activities is a characteristic common to all STPI countries. In the absence of a strong tradition of research in industry and of a weakness in the university research system, government organizations have dominated most areas of science and technology, and particularly those of an applied nature. The lack of independent industrial or educational sources of financing for science and technology forced the intervention of the state from the very first. However, the state's intervention in the STPI countries has not been totally coherent, and a multiplicity of channels has been established to finance the performance of science and technology activities. The diversity of channels, set up as responses to pressures from scientists, engineers, government officials, university authorities, research administrators, and industrialists, is largely accountable for the lack of coordination among the different government agencies in charge of supporting science and technology in the STPI countries.

In the STPI countries at the consolidation stage, research institutes, service organizations, university centres, consulting and engineering design firms, research groups within enterprises, and other similar organizations are capable of responding to the limited demands that emerge from industry and in many cases could respond to increased demands. For example, a detailed examination of the scientific and technological infrastructure and capabilities in the chemical process industries of Argentina showed that in 1973 there were sufficient qualified researchers, professionals, and technicians, as well as research centres, consulting firms, and other organizations, to fill the technical needs of industrial firms. They were providing substantial technical inputs but had the capacity to increase significantly their contributions without strain. However, the response capacity of industrial research centres in countries such as Argentina, Brazil, South Korea, and Mexico was mainly general, covering a variety of techniques common to many industrial activities, unsuited to the specific demands of industrial firms.

Within industrial firms, also, there are technical capabilities that have not been used fully. For example, a detailed study of research centres in Brazilian state enterprises in 1975 showed that they were capable of providing more substantial scientific and technical inputs to the enterprises they were part of. Also, a program started in 1970 in Perú to

induce industrial firms to perform scientific and technological activities met with a significant response, and a number of research projects, albeit of limited technical scope, were started by industrial enterprises in a relatively short time.

The obstacles to the increased use of local scientific and technological inputs by industry may not exclusively result from deficiencies in the performance of scientific and technological activities but may be due to factors limiting the demand for indigenous science and technology.

The common characteristics of science and technology in STPI countries all have their roots in the countries' history. The lack of demand for indigenous scientific and technological activity results from the patterns of industrialization; the marginality and isolation of the scientific communities are a consequence of the lack of demand and the attitudes of the scientists; and the lack of an appropriate climate for science and technology results from the deficiencies of the educational system, the inadequacy of the human resources base, and the prevalence of cultural factors that are not conducive to the growth of science.

From an historical perspective, it is possible to discern a connection between the patterns of industrial growth of STPI countries and the stage of development of their science and technology. Those countries that started import substitution early and had a large internal market (Argentina, Brazil, Mexico, India) were undergoing a process of consolidation in the mid-1970s, whereas the STPI countries that started their industrialization later and had a relatively smaller internal market (Colombia, Peru, Macedonia, and Venezuela) were at a formative stage. South Korea, which followed an industrialization strategy combining export promotion with import substitution, managed in a short time to develop its science and technology to the consolidation stage. From the beginning, South Korea focused on scientific and technological considerations.

At present, Brazil, South Korea, Mexico, and India are expanding their scientific and technological base. Brazil expects to increase resource allocations for science and technology by 10-fold between 1970 and 1980, and South Korea is expanding its network of research institutes, creating 10 new specialized research centres. Mexico has

decided to increase financial contributions to research activities and to reformulate the science and technology plan that was prepared in 1974-76. India is in the process of implementing its science and technology plan and is contemplating substantial increases in resources for key areas of scientific and technological activities.

Efforts to regulate imports of technology have begun in the STPI countries belonging to the Andean Pact (Colombia, Peru, and Venezuela), as well as in the larger countries such as Brazil, India, and Mexico. The liberal policy of South Korea with regards to technology imports in the late 1960s was followed by a more strict regulation of imports of foreign technology in the mid-1970s, and shifted again to a liberal position in the late 1970s. This was done in response to changing circumstances, particularly with regards to the capacity of private industry to negotiate better technology import agreements. There have also been programs to enhance the technological capabilities of industry, notably the efforts of the sectorial plans for science and technology in India, and the attempts of the Industrial Institute (ITINTEC) in Peru.

All the STPI countries have an exogenous scientific and technological base, having to confront the scientific and technological advances of the industrialized nations and relying massively on technology imports, but the countries with science and technology undergoing a process of consolidation are in a much better position to absorb, modify, and improve imported technology. They have an advantage over the countries with science and technology at the formative stage. The transition between the formative and consolidation stages is not automatic; it is closely linked to the nature of the industrialization process. It changes constantly as the environmental conditions change. The smaller STPI countries where science is still at the formative stage will have to confront not only the scientific and technological competition of the advanced industrial nations but also that from countries that are just undergoing consolidation.

Some Implications

The evolution of industry and of science and technology in STPI countries is the backdrop for examining ways of modifying the existing situation; it determines the "room for

maneuver" in the development of indigenous scientific and technological capabilities and the use of foreign technology. It places in perspective the possible role of the state, and more precisely, that of the policy instruments required to develop such capabilities. But the scope for action in science and technology development is conditioned not only by the S&T dynamics within the STPI countries but also by the international setting and the changes in the international distribution of industrial production.

The present distribution of world industrial production concentrates more than 90% of industry in the developed countries and is not likely to change significantly in the next decade or so. The distribution of international scientific and technological effort is even less likely to change, and at present Third World countries account for less than 5% of the personnel and financial resources. Some of the larger STPI countries, notably Brazil and India, may reach substantial levels of development in industry and in science and technology toward the end of the century, but even they will continue to be dependent on technology transfers from the developed countries for a large part of their modern industry.

The 1975 UNIDO General Conference in Lima, Perú, suggested that less-developed countries should aim for 25% of world industrial production by the year 2000, a cumulative annual rate of industrial growth well in excess of 8%. The early 70s saw a rate that hovered around 6% so the target proposed by UNIDO may be only a dream. The possibility that the less-developed countries may reach the level of scientific and technological development of the industrialized nations is even further off.⁵ In fact, it has been suggested that the less-developed countries will never be able to close the gap that separates them from the advanced industrial nations.⁶ For this reason, the efforts to develop indigenous scientific and technological capabilities in the less-developed countries will take place within the overall framework of an uneven distribution of industrial production and of scientific and technological activities.

The overall framework is relatively stationary, but within it, there is scope for improvement of industrial, scientific, and technological capabilities in the less-developed countries. The Western industrialized nations are undergoing a crisis,

often referred to as the crisis of capitalism, and the less-developed world has new opportunities to alter in some measure the existing international distribution of industrial production, and, to a lesser extent, that of the scientific and technological effort. The slowdown in economic growth, the problems associated with unemployment and the rising cost of labour, the problems of environmental disruption, and the uncertainties associated with the supply and price of raw materials and energy are inducing the developed countries to move their industrial activities to less-developed nations, retaining only the most advanced ones. Although the orientation and pace of technical change, particularly in the branches employing advanced technology, will continue under the control of the developed countries, some new opportunities will increasingly emerge for the less-developed countries.

The larger STPI countries with a relatively well-developed industrial structure and with science and technology undergoing a process of consolidation could take (and are taking) better advantage of the opportunities in the world redistribution of industry. The smaller STPI countries, having a less-developed industrial structure, with science and technology at the formative stage, will not be able to profit as much because the development of industrial science and technology is limited by the development of industry itself. A new stratification of the less-developed world is likely to emerge; in fact there are already signs of it as countries such as India, Brazil, Argentina, and South Korea export technologically complex industrial goods and even disembodied technology to other less-developed countries and, in a few cases, to industrially advanced countries.

⁵ For example, Schenkel considers that Latin American countries will take at least another century to reach the levels of scientific output of the industrialized nations of today. See P. Schenkel, "El replanteo de la política científica en los países de la OECD y sus implicancias para el desarrollo de la ciencia y la tecnología en América Latina" in K. Stanzick and P. Schenkel, eds. 1974, *Ensayos sobre Política Tecnológica en América Latina*, 1974. Quito, ILDIS, 162-163.

⁶ See, among others, R. Richta. *La Civilización en la Encrucijada*, Mexico, Siglo XXI, 68-71. For a contrary, and wildly optimistic view, see D. de Solla Price. 1965. *Little Science, Big Science*, New York, Columbia University Press.

The scope for state intervention in countries at different stages of development varies, and consequently the impact of policy instruments on the development of scientific and technological capabilities also changes. At present, it seems that full exploration of the room for maneuver open to the less-developed countries requires that the interests of the local industrial bourgeoisie coincide with those of the state. Given the present constraints imposed on the development of industrial science, this means broad and sustained government support to private industry (both foreign and local) and to research institutes, consulting firms, quality control agencies, and other science and technology infrastructure organizations, while measures are being taken to link the infrastructure with the industrial firms. The local private sector needs the S&T support that can be provided by the state to compete with foreign firms that have a technological

superiority, although this is not frequently realized or acknowledged by the local industrial bourgeoisie.

These remarks are by no means a value statement but rather an appreciation of the existing trends, constraints, and of the conditions under which scientific and technological capabilities for industry have developed and are likely to develop further in countries such as Argentina, Brazil, Colombia, South Korea, Mexico, and Venezuela. The situation faced by India, Macedonia, Egypt, and Perú has been somewhat different, but in Perú and Egypt the social and political changes in 1976-77 point in the same direction as the first group of countries. The only way to modify this situation radically would be through major transformations in the existing international economic order, and also in the social, economic, and political organization of the STPI countries, both of which do not appear likely in the near future.

Chapter 3

Implementing Science and Technology Policy

The development of scientific and technological capabilities for industry in the STPI countries will take place only as a result of determined government intervention. The different ways and means through which the state exerts its influence to shape industrialization and the development of industrial science and technology deserve special attention. State intervention takes place through a series of “policy instruments” whose general and conceptual characteristics have been spelled out in the methods guidelines of the STPI project (summarized on page 27). The guidelines are the starting point for identifying, describing, and evaluating the array of policy instruments employed by governments; they were adapted by the STPI teams to suit the situation.

There have been several previous attempts at examining and evaluating the impact of government policy instruments, particularly in the economic field. From a theoretical standpoint, Tinbergen (1964) studied the variety of policy instruments that could be used to achieve certain policy aims in several different economic models. His analysis was mainly concerned with economic policy formulation, the evaluation of the consistency between aims and means, and the suggestion of optimal policies to pursue certain aims. Taking a more programmatic view, Chenery (1958) proposed several development policies and a classification of the policy instruments available to pursue them. Sierra (1966), expanding on the concepts put forward by Chenery, emphasized the institutional character of the instruments of economic policy, focusing on the role of the state and on the conflicts that are likely to emerge because of the diverging interest groups struggling for control of the governmental apparatus. Based on a mass of empirical evidence and on very explicit value premises, Myrdal (1968) developed a conceptual framework for the

analysis of “operational controls” — the policy instruments of the STPI project — and reached many important conclusions about their economic impact, particularly on the private sector.

Another study described the aims and instruments of industrial policy in the developed countries (OECD 1975) and two other studies have dealt explicitly with the nature and impact of policy instruments to stimulate technological innovations in the industrialized nations. The first of these, conducted by national teams led by K. Pavitt at Sussex University (1974), was an exploratory study to examine the kinds of government intervention used to promote industrial innovation in Germany, France, the Netherlands, and the United Kingdom. The second was an extensive study of Western European and Japanese experiences on the promotion of technological innovation, conducted by a team led by H. Hollomon at the Massachusetts Institute of Technology (1976), with the aim of providing information for policy purposes to U.S. government agencies.

The difficulties in attempting an assessment of the nature and characteristics of government policy instruments have been highlighted by these studies. For example, Sierra (1966) cautions against attempts at evaluating any particular policy instrument in isolation, whereas Ashford *et al* (Center for Policy Alternatives 1976, p. III-41) warn that . . . it is impossible in most cases to separate the role played by government actions from the multitude of other causal and intervening factors. This is not to cast doubt on the influence of government mechanisms . . . but merely to cite the futility of trying to draw clear causal connections.

Focusing specifically on policies to stimulate innovation, Pavitt (1974) mentions the following difficulties: the lack of an easy,

universal way of measuring the output of government measures to promote innovations; the problems involved in attributing causality when examining relationships between specific government policy instrument “inputs,” and the “outputs” of knowledge, innovations, etc.; and the fact that the general economic, social, and political climate — the contextual factors of the STPI project — may have a bigger influence on some aspects of innovation performance than any specific government measures. For this reason, as Freeman (cited in Pavitt 1974, p. 96) points out, the assessment of government measures for technological innovation is a rather complex task:

We must not . . . expect too much from attempts to assess the merits . . . of systems used by government to stimulate industrial invention and innovation. The inherent difficulties of assessment are considerable, information is often scanty, interest groups are often heavily involved, and the possibilities of experimental verification severely limited. Nevertheless, if we approach the subject with the skeptical spirit of the natural sciences, and the historical sense of the social sciences, it may often be possible to raise the level of debate, understanding and research.

The guidelines for the STPI project proposed several classification schemes, which were used by the country teams at different stages of the research but which were not suitable for comparative analysis. Based on the impact of policy instruments on science and technology functions and activities, the material on policy instruments that was produced by the country teams is examined here according to the following categories:

- Policy instruments to build up an S&T infrastructure for the generation of technology;
- Policy instruments for the regulation of technology imports;
- Policy instruments to define the pattern of demand for technology;
- Policy instruments for the performance of S&T activities in enterprises;
- Policy instruments related to the support of S&T activities.

Most policy instruments overlap; there are many instruments that belong to two or even more of the categories. Nevertheless, the categories order the material and simplify comparisons. The frequent changes that government policies and their associated policy instruments undergo have made it necessary to limit analysis mainly to the mid-1970s and after.

Style of Implementation

The “style” of policy implementation in the STPI countries is based on the role of the state in orienting industrialization, and the way in which it intervenes to shape industry.⁷ In the STPI countries, with the exceptions of Perú and South Korea, the state has provided general support for industry, across a wide front, without attempting to define clearly the direction of industrial growth, leaving the structuring of industry primarily to market forces. Perú has adopted an authoritative style, with laws providing the framework for industrial growth with a clear definition of industrial priorities. South Korea has adopted a style of selective but intensive support of a few key industries (mainly the export-oriented branches) through close interaction of the state with private industry. Nevertheless, even in the countries that have left their industry to be shaped by market forces, there have been some efforts to stimulate specific branches, such as the capital goods industry in Brazil and Mexico, and the recent emphasis on industries that have an exporting potential in Colombia.

Another dimension of style refers to whether the state relies on “control” or “promotion” measures to support industrialization and the growth of S&T capabilities, that is, whether it relies more on restrictive and compulsory measures or on inducements and incentives to motivate entrepreneurs to behave in a desired way. Although the two options are not exclusive and in fact several countries have a combination of both, the majority of STPI countries, with the exception of Colombia and Perú, rely mostly on promotional measures that indiscriminately provide incentives to industry. All industrial enterprises equally benefit from the incentives, particularly in Mexico, Brazil, and Venezuela. In South Korea, promotional

⁷ Because of insufficient data, India, Egypt, and Macedonia are excluded from the analysis in this section.

measures have been geared to specific industries awarded priority by the government. Colombia and Peru are different because they both rely to a large extent on control measures and on restrictions imposed to guide industrial behaviour. In Colombia the control measures are a legacy of the import substitution policies followed for a long time within the framework of acute foreign exchange shortages and are complemented by a limited set of promotional measures offering credit and tax exemptions. In Peru, the restrictions emerged from the industrialization strategy adopted in the 1970s, which sought to strengthen the role of the state as the main force orienting industry and as a participant in direct productive activities.

All the control measures have concerned: foreign exchange (with the exception of oil-rich Venezuela); registration of foreign investments; and registration and negotiation of licencing agreements for technology transfer. The relative weight of the control measures has been conditioned by the number and weight of promotional measures, and in the countries that rely mostly on promotional measures their real impact is rather limited and circumscribed to formal registering procedures.

A third dimension of style is coherence in S&T policies. The outstanding case in this regard is South Korea, although Brazil follows closely. In Argentina, the S&T policies are not coherent, and they are divorced from industrialization policies. Mexico and Colombia would also fall in this category, were it not for recent efforts. The third situation, which includes Venezuela and Perú, is one in which the S&T policies are coherent but not integrated with industrialization policies. For example, Venezuela formulated a rather comprehensive and coherent S&T policy as part of the First Plan for Scientific and Technological Development and the Fifth National Development Plan but has not managed to develop the policy instruments necessary to put these policies into effect nor to integrate S&T policy with industrialization policies. Perú developed a highly sophisticated industrial S&T policy, but its industrialization policy and the overall S&T policy remained uncoordinated.

A fourth dimension of style refers to state intervention in implementing policies. The state may range from passive, simply setting the conditions for growth in private industry to interventionist, directly participating in key

productive activities, replacing private initiative in these areas, and establishing and enforcing regulations to guide the private sector. In all the STPI countries except Colombia, there are large state enterprises that supply industrial services (electricity, industrial parks) and basic industrial products (oil and steel). They are supposed to provide basic industrial inputs at a low price to stimulate the growth of industry while paying their own way. The extreme case of state intervention in productive activities among STPI countries is in Perú, where the state has been the major source of industrial investment during the 1970s and where state enterprises have extended to a variety of industrial activities, severely limiting the scope of private industry. In the late 1970s, Venezuela has also adopted a rather aggressive stance, intervening in basic productive activities with massive infrastructure investments and the creation of very large state enterprises in the fields of steel, oil, and gas.

The state may intervene by setting policies in its development plan. In Perú, the plan has become a major instrument of economic and industrial policy, and in Venezuela, where the plans to invest the revenues obtained from oil exports have become very important, the overall plan has also acquired greater importance, particularly with reference to the large industrial complexes. The development plan in South Korea is also very important, although the close interaction between the government and private industry in the planning process give it a special character. In Brazil, development plans are almost a collection of investment projects of the various ministries and state enterprises, and the planning mechanism is rather loose. For all practical purposes, Argentina, Colombia, and Mexico do not engage actively in planning the development of industry.

Argentina, Colombia, Mexico, and Venezuela intervene very little in the direct regulation of industrial activity, preferring to rely on promotional instruments that leave the initiative to the private entrepreneur. However, in Mexico, and to a lesser extent in Colombia and Venezuela, state financing of industry is extremely important and could have a great impact on the regulation and orientation of industrial activities. Brazil, South Korea, and Perú intervene extensively in the regulation of industry employing a

variety of legislative measures and operational controls. In these three countries, one of the main mechanisms for the regulation of industrial activities has been government financing through development banks.

The array of policy instruments employed to orient the development of industry and the growth of scientific and technological capabilities has been characterized in different ways by the various country teams in the STPI project. However, there are a few common characteristics that are worth highlighting before they are examined on a country-by-country basis.

In most countries, policy instruments are rather general; in other words, they lack selectivity, applying across the board to all types of industries. A large number are also dependent on the discretion of a particular government agency in charge of applying them. Although, in theory, the agency can focus them in a precise way, the lack of selectivity of the instruments does not provide a good basis to exercise discretionary power, and the lack of qualified personnel and of administrative capabilities makes the discretionary qualities of policy instruments a rather neutral (and in the case of corruption, even negative) characteristic. For the most part, the instruments designed as incentives are passive — the beneficiaries are supposed to take the initiative with respect to their application.

The common features in the style of policy implementation of STPI countries are a good introduction to a more detailed look at the individual styles.

Argentina

In Argentina, one of the most outstanding features of the evolution of scientific and technological activities during the last 20 years has been the lack of an explicit and coherent frame of reference, with sufficient continuity and strength to orient the development of scientific and technological capabilities and induce changes in the behaviour of entrepreneurs. For example, since 1960 Argentina has had six different development plans that have been in effect for periods that range from 6 months to 2 years. There have been some attempts at formulating "operational plans" for science and technology, but they have not had any impact. The agency in charge of formulating and

implementing S&T policy has suffered a variety of institutional transformations, fluctuating from a National Council, to a subsecretariat of the Secretariat for Education, and finally becoming a Secretariat. The frequent institutional and policy changes have made S&T policies and policy instruments ambiguous and even contradictory.

The main characteristics of Argentina's S&T policy instruments are their heterogeneity, passivity, and marginality. There is a heterogeneous set of policy instruments in operation, with several identifiable "vintages" corresponding to the periods in which different groups were in power in Argentina. The instruments act in a variety of ways and even contradict each other. Furthermore, the government's administrative decisions, lacking overall guidelines, accentuate the ambiguous and contradictory character of the policy instruments.

All the policy instruments are passive, leaving the initiative in the hands of the private sector. There is not a single policy instrument that operates in a coercive way. With the sole exception of the registry of licencing agreements, all policy instruments offer the private sector a series of incentives and benefits that are available to private enterprises at their convenience. The state has no means to differentiate in the treatment of enterprises nor any mechanisms to define priorities for the development of technological capabilities.

S&T policy instruments in Argentina exhibit marginality. For example, technology is declared as one of the criteria for the application of an instrument of industrial policy but is not actually employed. Policy instruments are marginal also in the sense that they do not affect the key technological decisions of industry.

The heterogeneity, passivity, and marginality of policy instruments in Argentina combine to cancel any impact on technological behaviour and technical change in industry. Special credit lines for pilot plants and prototypes, tax incentives for R&D, promotion laws, and other policy instruments have had little impact and have been applied in few occasions. This fact became evident when the country team studied the machine tool and petrochemical industries. It was underlined in the studies of engineering firms and a detailed analysis of 18 policy instruments.

Brazil

In Brazil, during the last 20 years policy instruments have gradually evolved in two main directions: toward increasing sophistication in their design and use and toward fragmentation due to several of the government's sectorial development programs. Together with these two trends, a basic characteristic emerges clearly: pragmatism, which has marked the adoption of a large part of the measures of economic and industrial policy. This pragmatism should not be considered as a response to the lack of global planning but rather as a reaction on the part of policymakers to unforeseen circumstances and problems, which, to a large extent, escape the sphere of government action and are the result of a sum of short-term actions in the process of industrial development.

The increasing participation of the state in the economy as a whole — both as a productive agent and as a regulator of productive activities — far from being the result of explicit decisions, has originated from circumstances beyond the control of the state. International crises, insufficiencies in infrastructure, bottlenecks in services, the need for foreign capital, and also the inability of the Brazilian private sector to provide the large sums required for investments with a long period of maturation have pressured the state to intervene directly as a productive agent. However, state intervention has not progressed linearly and continuously but rather in an uneven way with advances and retreats and with changes in emphasis in its role as entrepreneur and regulator of economic activity.

Within the framework of increasing, if not oscillating, state intervention, policies for science and technology, as far as they can be extracted from the development plans, have alternated between two goals. Either they have been reactive, catering to the needs of industrial growth or they have attempted to reorient the demand for technology. The first aims at satisfying the technological requirements of industry by speeding up the incorporation and diffusion of innovations, be they foreign or local, and the second aims at reducing the use of imported technology and expanding local capabilities for generating, adopting, and incorporating technical knowledge. The different plans put into effect during the last 20 years in Brazil

have carried implicitly one or the other goal, and the policy instruments have also reflected them.

Brazil has emphasized financial mechanisms to foster local scientific and technological capabilities, primarily funding institutions for the supply of knowledge. In fact, at times, some institutions have had difficulties in absorbing the financial resources. As an illustration, the Second Basic Plan for Scientific and Technological Development considered an ambitious program that sought to expand the scientific and technological infrastructure in the second half of the 1970s and implied almost a 10-fold increase in funds over the allocations made in the late 1960s.

Colombia

In general, Colombia's S&T policy and policy instruments have been characterized by a restrictive or defensive approach, in which the state has been interested primarily in preventing situations that could hamper the country's scientific and technological development. This approach is closely related to import substitution and the protectionist measures to deal with shortages of foreign exchange.

The defensive approach emphasizes regulations to reduce costs and to control the conditions under which foreign technology is transferred. In fact, the system for regulating technology imports was originally conceived as an instrument for solving balance of payments problems in the face of scarcities of foreign exchange.

The adoption of a restrictive or defensive approach, with emphasis on control measures, has not meant that promotional instruments have been nonexistent. Research and development activities have been actively promoted through the creation of government institutions and through financial mechanisms, even though there have been no policy instruments designed either to encourage the performance of S&T activities in enterprises or to diminish the risks of innovation.

As a consequence of the defensive approach, Colombia's degree and mode of state intervention has been rather ambiguous. Whereas the state has actively used control or regulatory policy instruments, granting permits and approvals, it has only passively

used promotional policy instruments, providing incentives for private enterprises without directing them.

An examination of 19 key S&T policy instruments in Colombia showed that the majority lacked selectivity, were applied across the board, and could not be used to promote the development of S&T capabilities in specific areas of potential interest. Furthermore, most policy instruments tended to be nondiscretionary and general. There were even a few instances where policy instruments lacked a set of policies to guide their operation.

Recent changes in Colombian policies and increases in foreign exchange due to high coffee prices and other exports have led to a shift from the protectionist measures of the import substitution strategy to liberal trade and increased promotional measures. This shift has implied a gradual move from the restrictive or defensive approach to a more promotional and liberal one.

South Korea

In South Korea, the approach to S&T policy design and implementation has been strongly conditioned by the industrialization policy which is aimed at developing selected strategic industries considered essential for rapid industrialization and for the expansion of exports. In this context, promotional laws have been drawn up to provide strong incentives in selected fields and to encourage foreign investment. In addition, the state has directly assisted industry by developing industrial sites and harbours and by reducing tariffs on imports of capital goods and raw materials.

The style of policy implementation in Korea has been mainly promotional, focusing on rapid development of selected strategic branches of industry. There has been a heavy reliance on foreign technology and investment to speed development. This reliance on foreign sources has been strengthened by the country's export policy, expansion of which has been based on the production of goods manufactured in the industrialized countries and suited to their consumer tastes. The need for foreign capital and technology for rapid industrialization has inhibited strong regulation of technology imports, and, likewise, the efforts to absorb foreign technology.

Some of the promotional measures, however, have been directed toward expanding the infrastructure for the performance of S&T activities. A large number of research centres and educational institutions have been established, particularly around the Seoul Science Park, and the creation of 10 new research centres is under way.

The extensive use of financial policy instruments by the state and the active role played by government agencies in the coordination and promotion of S&T policy are two additional characteristics of the Korean style. A characteristic of policy instruments is redundancy, particularly in promotional measures directed toward export-oriented industries.

The extensive intervention of government agencies into industrial activities has brought about a certain lack of flexibility, which is increased by the budgetary controls that government agencies have to go through. The promulgation of legal devices is one of the most important mechanisms for the promotion of S&T activities, and there is an array of formal laws or regulations that constitute an extensive legal system for the promotion of science and technology. Many of the measures have not proven their effectiveness and have not been widely implemented partly because of their short history. It may be too early yet to evaluate the results of the various policies put into effect through the legal devices.

Recent trends in South Korean S&T policy indicate that technological factors are to be given greater importance in the late 1970s and the 1980s. The move has been toward replacing labour-intensive industry by technology or "brain"-intensive industries and depending less on foreign capital. There is a recognition that, with a lack of natural resources, South Korea has to depend on technology as the key factor in future development. In the 5-year plan that began in 1977, technological development was one of the three main targets to be achieved.

There has also been a recognition that past policies have not been effectively coordinated and have not been supported by effective policy instruments. Thus, emphasis has been placed on attaining coherence among various policies and on providing effective promotional measures. The underlying

philosophy is that technology will develop in an environment where there is strong motivation to increase industrial efficiency. The motivation will create a demand for technology, the supply of which will be possible because of positive measures such as financing. Therefore, trends in Korean S&T policy point in the direction of continuing reliance on promotional measures but moving toward overall coherence and better implementation.

Mexico

In general, the state in Mexico has adopted a promotional style of S&T policy design and implementation, using incentives and positive stimuli to influence industrial enterprises. The incentives include providing a protected market, ensuring low prices in raw materials and services for industry, and offering fiscal inducements and tax rebates. The measures are geared mainly to reducing costs and increasing liquidity in industrial firms. Closely related to their positive or promotional character is their passivity, the initiative for their application coming from the beneficiaries.

The decisions on investment, goods to be produced, and techniques to be employed are based on the whims of the local market for manufactured products (and consequently the pattern of concentration of income). The strategy of industrialization has consisted in ignoring sectorial priorities, encouraging capital formation in any industry, and supporting indiscriminate expansion in any industrial branch. The lack of selectivity is one of the main characteristics in the Mexican style.

S&T policy instruments in Mexico are quite heterogeneous and defy attempts to categorize them. For example, a large number of policy instruments could be classified simultaneously as promotional and control instruments, mainly because of the dual character of their legal and operational mechanisms and because of the different perceptions of the various actors involved: what local industry may consider as an encouragement, a transnational corporation may see as a control.

Another characteristic of Mexican S&T policy instruments is that, for the most part, they act indirectly, modifying the conditions

under which private firms operate. Several involve a large amount of discretion on the part of the agencies that apply them. At times, the administrative authorities even assume legislative powers and, by exerting their discretion go beyond the terms of the law that gave them authority in the first place.

Another characteristic of the array of policy instruments is redundancy. The promotional measures concede benefit after benefit on top of each other and concentrate benefits in the few enterprises that apply for them (p. 81).

Until recently in Mexico, a firm was considered "national" if it were constituted in accordance with Mexican law and had an address in the country. In other words, foreign and local enterprises were on equal footing. Recent legislation on foreign investment, however, has introduced means to differentiate in the treatment of local and foreign enterprises.

In short, the overall style of policy implementation in Mexico is promotional. A large number of passive policy instruments give benefits to private enterprise, and market forces determine the main technological decisions, the state taking a rather passive role.

Perú

The style of industrial and S&T policy implementation in Perú has been different from that of the other STPI countries. The series of accelerated socioeconomic transformations instituted in the late 1960s and early 1970s involved a larger role of the state in the regulation and conduct of productive activities, stringent regulations for private industry, a system of compulsory worker's participation in ownership and management of industrial enterprises, and a detailed definition of industrial priorities. However, the changes were put into effect mainly through legislation, the lack of organization and operational mechanisms severely limiting their application.

The Peruvian style of policy implementation is oriented toward control and regulation of industrial and S&T activities; the promotional measures are embedded within a system of compulsory laws and regulations. However, the excessively legalistic character of the policy instruments has meant that they have been mainly formal and have had limited impact on industrial activities; even the

promotional measures contained in the laws have had little impact. Indeed, it has been reported that industrial entrepreneurs make their decisions and then look for ways to capitalize on the legal benefits.

Many government agencies are involved in policy implementation in Peru, and, because of the generality of the laws, the agencies have been vested with exceptional discretionary power, which they frequently abuse.

State enterprises play an extended role in Peruvian industry but, to date, have not been considered as tools for S&T policies. Emphasis has been placed on their rapid growth rather than on the development of local S&T capabilities.

The state has intervened more effectively to promote S&T research. In the early 1970s, the Peruvian government created a network of sectorial research funds and institutions and compelled all enterprises (local, private, foreign, state) to devote a certain percentage of their net income before taxes to S&T activities, under the supervision of the pertinent sectorial agency. Thus, since the late 1960s, the funds available for industrial technological research have increased 10-fold, a sizable, but not phenomenal, improvement over the negligible investment throughout the 60s.

Recent changes in government policy, brought about mainly by the financial crisis of 1974-76, have reduced the scope for state intervention in the conduct and regulation of productive activities and have modified some of the reforms introduced in the early 1970s. Also, considerations regarding the development of industrial technological capabilities have been pushed into the background, with a new emphasis placed on attracting foreign investment, liberalizing technology imports, and achieving rapid industrial growth. As a consequence, the style of S&T policy design and implementation has undergone changes, shifting noticeably toward promotion.

Venezuela

The set of industrial and S&T policy instruments in Venezuela provides a large number of incentives to industrial enterprises and includes few control measures. Until recently, it has not particularly encouraged the development of local S&T capabilities. Instead, it fostered technology imports, relying on foreign exchange from oil exports.

The policy instruments reflected the industrialization strategy, which emphasized the indiscriminate import of foreign technology and of technology-intensive capital goods and intermediate products required for the production of consumer goods.

During the mid-1970s, however, a series of "explicit" policy statements contained in the First Plan for Scientific and Technological Development and the Fifth National Development Plan acquired importance, and explicit policy instruments to expand local S&T capabilities were given greater play. New institutions were created; regulations controlling foreign investment and technology were put into effect; and several legislative initiatives were undertaken to increase the availability of funds for S&T, to deal with industrial property, and to establish a system of quality control and standards. Unfortunately, the "implicit" policy instruments associated with the industrialization strategy have subverted the possible impact of the new instruments, and the inherent deficiencies of "explicit" S&T instruments, along with the diverging interests of power groups that are involved in their application have acted against them.

Explicit policy instruments do not form a coherent and powerful influence, for they lack selectivity, are highly general, and involve a high degree of discretionary power. Furthermore, there are key gaps in their design and operation so that their combined effect is rather weak. In Venezuela, they are particularly ineffective because of the frequent changes and inherent instability of the government agencies that apply them.

The government has recently focused on rapid growth and industrial modernization, investing massive amounts in industry and indirectly fostering technology imports. It appears that the aim is to develop limited local S&T capabilities geared to absorbing some foreign technology, but the chances are slim for mastering the highly sophisticated and advanced technologies that are being imported for the large investment projects.

In brief, although Venezuela tacitly supports the development of local S&T capabilities, the country's industrial strategies place emphasis on the acquisition of foreign technology, with few controls to regulate the flow of imported technology and with a limited effort at developing the local

infrastructure for the performance of S&T activities.

Other STPI Countries

Because of the scarcity of information available on Egypt, India, and the Federal Republic of Macedonia in Yugoslavia, only a few comments are presented here to convey a glimpse of their style of policy implementation.

In Egypt, where state enterprises predominate in industry, the state regulates and controls policy implementation and devotes little attention to promotional measures. In India, the electronics sector, the only one for which information was available, is characterized by heavy state involvement in designing policies, planning industrial activities, and even producing goods, although the existing regulations include a framework of incentives for private industry and foreign investment, particularly in the manufacture of electronic products for export.

The special character of the Yugoslav economy, with the dominant role of self-managed enterprises in industrial activities, makes comparisons with other STPI countries difficult. It may be said that the federal and state regulations provide the framework within which self-managed enterprises operate. There are some promotional measures within the extensive regulations, combining with a system of controls to characterize the style of policy implementation in the Republic of Macedonia.

Among the STPI countries, there is great diversity in policy implementation, and it is almost impossible to define a model (or models) of policy implementation. Each country must be analyzed separately, even though it may be traveling in the same general direction as another country. The different ways in which measures are devised, combined, and modified over time make simple generalizations impossible.

In fact, the choice of a particular industrialization strategy and of a particular approach to S&T development still leaves ample room to tailor the set of policy instruments in accordance to the specific conditions of the country and the administrative style of the government. The key to the variety of styles is the state and the

conflicting interests of those involved in the struggle for control of the state apparatus.

In effect, the specific characteristics of industrial and S&T policies and of the array of policy instruments used to implement them depend on the degree of influence of the various interest groups within the state machinery. When there are frequent shifts in the hegemony of different interest groups (as has been the case in Argentina), the style of policy implementation becomes heterogeneous and acquires very peculiar characteristics.

The pervasive influence of the state means that great care must be exercised in extrapolating the analysis that follows. Variations in the industrialization strategies, in the evolution of scientific and technological capabilities, and in the styles of policy implementation constitute the specific context within which policy instruments operate and are the bane of policy prescriptions.

Building Infrastructure

One cluster of policy instruments is concerned with the development of indigenous capabilities for the supply of scientific and technological knowledge. It comprises the measures to establish, develop, and orient the growth of institutions involved in the performance of S&T activities and of programs and projects within these institutions. The traditional concept of "science policy," which gained acceptance during the 1950s and 1960s, focused almost exclusively on this aspect of S&T development and emphasized the creation not only of R&D and supporting organizations, but also of science policy bodies.

Building an infrastructure for the generation of technology is especially important in the formative stage of S&T capabilities; it becomes less paramount during the consolidation stage and later. The three main policy instruments in this cluster are institution building, science and technology planning, and financing of S&T activities. During the formative stage, institution building is more important than the other two, although planning for the creation of S&T capabilities in selected areas is also important.

During the consolidation stage, institution building takes a back seat, filling in gaps in the S&T capacity; and S&T planning is focused on the use of existing capabilities and the rationalization of S&T activities. Financial measures are equally important in the two stages, although in the latter they focus on specific programs and projects rather than on the general financing of institutions. These three policy instruments are complemented by government administrative measures for the import of equipment and inputs, exemptions from government budgetary regulations, and so on.

The combined effect of institution building, S&T planning, S&T financing, and administrative facilities takes time to surface. Frequent institutional and other changes observed in several of the STPI countries work against it and slow the development of an adequate S&T infrastructure.

One of the crucial components in building an infrastructure is personnel training because institutions are made of people. However, this aspect was covered only marginally in the STPI project and receives only passing reference in this report.

Institution Building

S&T institutions in the STPI countries range from those impelled spontaneously by scientific groups, government agencies, and industrial enterprises, to those planted firmly within national development policies and included in the science and technology development plans. As a purposeful policy instrument, institution building is of relatively recent origin and has not yet crystallized into a recognizable set of procedures, guidelines, and methods.

The institutions that comprise an S&T infrastructure may be classified in many ways, encompassing R&D, service, education, training, policymaking, etc. activities; they are not created in a vacuum but rather in the context of the economic and social development of a given country. For example, to a large extent, the institutions concerned with industrial science and technology in STPI countries have emerged during the last 30

years as a result of pressures from the industrialization process itself.⁸

Although institution building is an instrument to develop the S&T infrastructure, few government officials explore its potential. Most policymakers are not even aware of the importance of the S&T infrastructure for development. Whereas institution building is not controversial and is not likely to generate determined opposition, there are constraints imposed by the lack of financial and qualified human resources. There are also pitfalls: indefinite institution building. When a large number of S&T institutions are created and the institutional infrastructure expands without a corresponding increase in the demand for its services, institutions become self-centred, paying little or no attention to the requirements of industrialization and isolating themselves.

In Argentina, the network of institutions involved in S&T activities has grown in a piecemeal fashion over the years, but the lack of coordination has not precluded notable achievements in several areas of industry, agriculture, basic research, and even military S&T activities. At the centre of the industrial efforts is the National Institute of Industrial Technology (INTI), which emerged from a joint effort of the state and the industrial sector. The institute has been structured to respond to industry's demands, creating new centres and laboratories as the need for their services arises.

Like Argentina, India has experienced piecemeal institutional development in science and technology, mainly resulting from sectorial initiatives with little overall coordination. Since independence, institution building has been considerable, and the 1974-77 S&T plan was mainly concerned with how to put the existing S&T institutions more into the service of development objectives. Although the plan also proposed incremental expansion of existing organizations to undertake new programs, it did not represent a tightly integrated program for institution building but rather an aggregate of initiatives from various government S&T agencies.

The Indian S&T plan is in some ways similar to Brazil's Second Basic Plan for Scientific and Technological Development; they both call for additions and modifications to existing institutions, but the latter also advances the creation of new institutions around several "technological complexes" that would

⁸ See page 47 for more detailed discussion.

integrate research centres, engineering firms, and high-technology industries. This notion of concentrating several research centres, S&T service institutions, engineering firms, and industrial firms to provide a critical mass of S&T activities is also present in the Korean concept of a "science park" or a "science town."

South Korea is the one STPI country that has used institution building as a major instrument of S&T policy; it has, thus, produced a tightly knit network of S&T institutions that include a Ministry of Science and Technology, a graduate science school (KAIS), an information centre (KORSTIC), and an expanding group of research institutes. Several of these organizations are located in the Seoul Science Park where the idea has been to create the conditions for efficient scientific and technological work. The South Korean S&T institutions are a product of very special conditions. The support of the United States has been crucial in building key institutions, such as the Korean Institute of Science and Technology (KIST), and there has been a large pool of highly trained South Korean scientists working abroad who have returned to work in the new S&T institutions.

In Perú, institutions for science and technology have evolved along sectorial lines, with a network of research centres and independent funds being created for industry, agriculture, mining, and fisheries. There has been a lack of overall coordination, but the main bottleneck has been the lack of qualified human resources. After a good start in the early 1970s, the network of institutions reached a crisis in personnel in the late 1970s.

In summary, institution building as a policy instrument has been used explicitly at the national level in just a few cases, notably in South Korea where it has been rather successful. In Perú, general sectorial institutions have been established, but no overall policy in institution building can be discerned. In Argentina, India, and Brazil, S&T institutions have not been built as a result of determined government policy but rather as expressions of certain interest groups; thus, they represent not the means to an end but the end itself. The lack of coordination and direction has meant that the infrastructure has grown in a gradual way. Nevertheless, the infrastructure does exist, and, thus, institution building is no longer the most important policy instrument; it has been superseded in these countries by planning.

S&T Planning

Development planning, which aims at orienting and regulating activities and the services necessary for them, implies technological needs that, in turn, imply scientific and technological activities. Development planning is an instrument for both explicit introduction of science and technology issues and implicit introduction of technology policies.

Science and technology planning is a policy instrument in itself; it consists of the procedures, organizational arrangements, methods, etc. to tackle the development of scientific and technological capabilities, determining priorities for S&T, allocating resources, and defining S&T activities.

To take planning seriously, governments cannot plan science and technology without considering the demand for S&T activities derived from the development plan. Every development strategy — and particularly an industrial one — embeds technological needs and defines S&T requirements.

In S&T planning, the first task is to spell out the technological implications of the development plan, isolating the technology required, the constraints imposed by the projects, the natural resources needed, the targets, and so on. The next step is to introduce science and technology as a strategic variable, such as employment and financing, into the plan.

The final plan then reflects the stage of S&T development, i.e., whether it is necessary to create an S&T capacity and develop it in a major way or mainly to reorient the existing S&T capacity and complement it in strategic areas. For this reason, the experience of S&T planning in the developed countries is of little relevance to countries such as those of the STPI project.

The organizational structures for S&T planning in STPI countries are similar. The scientific community participates through a number of committees that correspond to a central coordinating body. There are differences in the composition of the committees, in their number and size, and in their relative autonomy and power, but their objective is the same.

The 1974-77 Argentine development plan exemplifies some of the inconsistencies that result when technological implications are not linked with the declared aims of S&T development. In the end, technological

considerations were pushed into the background, and the plan was not put into effect.

Analysis of Brazilian development plans 1953-73 tells a different story: implicit technological considerations were in agreement with S&T policies, the strategy for S&T development following the path established by the economic development strategy. In addition, the first and second basic plans for scientific and technological development attempted to consolidate and order the S&T activities performed and supported by the state. The first one was mainly a collection of projects presented and financed by the various government agencies, whereas the second moved ahead in the definition of S&T strategy and proposed several new programs that responded to the main objectives of Brazilian development policies. Furthermore, the S&T planning process was closely associated with the allocation of financial resources, and the plans contemplated large increases in funding for S&T activities.

Colombia has put emphasis on the preparation and implementation of sectorial S&T plans, and planning has revolved around food and nutrition (following closely the food and nutrition plan of the national planning department), housing development, and the marine sciences.

Egypt has experienced a large number of changes in the institutions responsible for S&T planning during the last 25 years, and, as a consequence, most of the plans have not been implemented. To date, S&T planning in Egypt has been almost exclusively concerned with the planning of R&D under the aegis of the Academy for Scientific Research and Technology.

S&T planning is most sophisticated in India, where a series of sectorial plans have been developed within a common framework that enables decisions on resource allocation and priorities for S&T among the different sectors. The existing plan was a rather large exercise in which several hundred scientists, engineers, industrialists, and government officials participated actively. Priorities and strategies for S&T development were closely associated with India's development plan.

The Mexican Science and Technology Council engaged in a planning exercise similar to the one in India. Around 20 committees were formed to deal with scientific disciplines and technological problems, as well as a

number of issues common to both science and technology, such as human resources, S&T services, and policy instruments. Mexican planners faced the determined opposition of some sectors of the scientific community (as did the Indian planners) but were able to gain a consensus on the plan's application. However, a change in government in late 1976 brought in new authorities who left the plan aside and, for the most part, still have not implemented it.

The Venezuelan plan for science and technology was also prepared through a participatory exercise, and like the Mexican plan, has not been fully implemented. Some of the programs have suffered several delays, and institutional changes in the agency in charge of putting the plan into practice have hampered progress. Another obstacle to implementation has been the determined effort made by the government to expand industry very rapidly, relying mainly on massive technology transfers.

South Korea represents a special case, primarily because its economic development plans fully integrate technological considerations; in fact technological development is one of the three main targets of the development plan that began in 1977. South Korea is unique also because it has made a determined effort to link economic and S&T planning. This has led to the identification of a number of "key technologies" that need to be mastered in order for the economic plan to achieve its objectives. Scientific and technological efforts are organized and promoted around these key areas, and 10 new research institutes are being established in the late 1970s to provide S&T support. Furthermore, planning has been closely associated with the allocation of financial resources for science and technology and with a series of incentives for private industries to master the "key technologies."

Financing S&T Activities

The link with financial resources is crucial, and a set of financial mechanisms is essential, for building up an S&T infrastructure as well as for implementing S&T plans. It is one that takes a long time to consolidate.

In general, the allocation of financial resources is bounded from below by the minimum amount of funds necessary to sustain S&T activities and from above by the

absorption capacity of the institutions engaged in the performance of S&T activities. The two limits are difficult, but essential, to define, according to the experience of STPI countries; otherwise, the proper handling of S&T financial mechanisms is impossible, and some S&T activities will be allocated too little and others, too much.

A country's financial resources during its formative stage are allocated primarily to institution building whereas later they are often devoted to well-defined programs and projects for the performance of S&T activities. In the latter case, greater emphasis can be placed on contract research, which forces R&D institutions to deliver results in a systematic manner.

There are three basic ways to acquire funds for science and technology. The first involves legal measures stipulating automatic contributions to an S&T fund that is not subject to budgetary negotiations at the government level. This is exemplified in the research fund managed by ITINTEC in Peru, to which all industrial enterprises are obliged to contribute 2% of their net income before taxes. Another example is the Argentine fund for INTI, which receives 0.25% of the credits awarded to industry by the National Development Bank. The second method is to secure intersectorial transfers from government agencies and institutions. The National Fund for Scientific and Technological Development and the Fund for Technological Development in Brazil are examples. The third is a form of marketing, in which the institutions performing S&T activities work under contract to a client. Of the three, the first guarantees the most steady flow of funds.

No matter how the funds are acquired, they may be disbursed either through a central agency or through a variety of decentralized authorities. At present, the general trend is toward establishing a variety of research funds that respond to initiatives in specific sectors and that are not subject to the dangers of excessive bureaucracy common to centralized funds.

For instance, Argentina has developed several funds for the support of S&T activities. It heavily funds research institutions and individual researchers, the latter through a direct subsidy associated with the "professional researcher career"—a mechanism to ensure researchers receive sufficient financial support to devote their time fully to research.

Brazil has also developed several multi-purpose funds that cover a wide range of activities and possible beneficiaries; in addition, it has relied on extensive budget transfers to state-supported S&T institutions. These mechanisms aim at increasing the availability of financial resources for S&T to the level of around U.S. \$800 million annually by the end of the 1970s, a 10-fold increase since the late 1960s. Colombia has financed S&T activities mainly through a central fund of rather modest proportions and through budgetary transfers to state research institutes. In India, allocations for S&T activities are handled mainly by the various ministries, although there are also several sectorial funds of lesser importance, and the use of S&T funding mechanisms is closely associated with the process of S&T planning. In Mexico, financial allocations for S&T are handled primarily by the various ministries, although a central fund, amounting to about 15% of total S&T allocations, is managed by the National Council for Science and Technology. South Korea attaches great importance to S&T funding, and the government intervenes very actively through a variety of funds and mechanisms under the general coordination of the Ministry of Science and Technology.

In Peru, there is a network of compulsory sectorial funds for research, but contributions are based on percentages of gross profits of the firms in the various sectors and are threatened by economic crisis. Venezuela has increased substantially the allocations for S&T as part of the government budget; in fact its financing has at times outstripped the absorption capacity of research centres and institutions. The Venezuelan government is studying the establishment of a central fund with contributions obtained from a certain percentage of the turnover of industrial firms.

Regulating Technology Imports

Another cluster of policy instruments aims at regulating the flow of technology into a country, both embodied technology (machinery, equipment, or intermediate products) and disembodied technology (technical know-how, patents, technical assistance, management procedures, etc.).

The regulation of technology imports is

particularly important in less-developed countries because imports often determine the technological structure of industry, defining the level and characteristics of the technological base. Indiscriminate importing usually stunts the growth of domestic technological capabilities, and although technology imports should not be eliminated, they should be carefully regulated.

Regulating imports became popular in the late 1960s and early 1970s in the less-developed countries, mainly as a reaction against the abuses of foreign technology suppliers (overpricing of intermediate inputs, imposition of restrictions to the technology buyer, excessive royalty payments, etc.). In some of the STPI countries, such as Colombia, the initial drive for controlling the import of technology was prompted by financial or balance of payments considerations, and technological issues were introduced at a later stage.

The regulation of technology imports involves conflicting interests, several government agencies, and a variety of different policy instruments. It is almost impossible to use all the policy instruments available for this purpose and combine them in a coherent and effective way. None of the STPI countries have managed to do this.

All the policy instruments in this cluster have more than one objective or function to fulfill. For example, import controls are aimed at protecting local industry, at reducing balance of payments problems, at generating revenues for the state, and also at fostering growth in selected technological capabilities. Foreign investment controls and regulations aim at setting the conditions under which foreign capital is allowed in the country to accelerate industrial growth, to promote exports, or to encourage the establishment of selected industries that may contribute to local S&T development. The patent system is supposed to encourage local invention and innovation, but its effect has been felt mainly in the grants to foreign technology suppliers. Similar remarks apply to joint ventures and the registries of licencing agreements. The fact is that this constellation of multiple objectives makes the coherent application of this cluster of policy instruments rather difficult.

The conflicts that emerge when import regulations are strictly applied include slower industrial growth (by controlling the introduction of new products and techniques); increased prices (because

domestic production is likely to be initially less efficient and local costs higher); poorer product quality (because of the lack of experience in local manufacturing); and scarcities of certain goods (because of insufficiencies in domestic production). Furthermore, foreign technology suppliers and investors may be driven away by increased controls. In the face of these possible effects, many interest groups — local entrepreneurs, foreign investors, traders — frequently oppose import regulations.

However, the regulation of technology imports may protect infant industries and stimulate their development, lead to a better balance of payments, generate increases in employment, and promote the development of local S&T capabilities. In effect, new industries may be given the opportunity to become more efficient before facing competition from imported products; industrial balance of payments problems may be ameliorated by import controls and the regulation of foreign investment; limitations on machinery imports may encourage more intensive use of domestic resources, particularly labour; and local scientists, engineers, and technicians may expand their problem-solving capacity.

In other words, the regulation of technology imports provides the opportunity for local S&T capabilities to develop but produces conflicts that limit its application. The technological aims must be weighed against nontechnological objectives to reach a balance, a condition that is rarely found when this cluster of policy instruments is enforced.

Import Controls

All less-developed countries employ a number of policy instruments to control incoming goods from foreign countries. Their main goals are to protect local industry and to stabilize the balance of payments. The array of import controls is vast: tariffs, customs exemptions, import permits, import prohibitions, import lists, import quotas, foreign exchange control and restrictions, differential exchange rates, import committees, state import monopolies, etc., are all used for the purpose of discouraging and restricting certain kinds of imports.

Import controls have an indirect or implicit effect on the technological structure of

industry, for they determine the types of capital goods and intermediate products — both of which embody technology — that will be allowed into a country and incorporated into production. They are also a means of promoting local technology in manufacturing specific goods.

In the STPI countries, import controls have usually been applied to further import substitution; hence, their application should be viewed in the context of industrialization strategies. Of particular interest is the fact that import controls have been applied mainly to consumer goods and to a lesser extent to capital goods and manufacturing inputs. This has affected and distorted the internal productive structure and has not provided incentives for the development of capital goods industries.

Import controls have both short and long-term effects upon industrial activities and the development of domestic S&T capabilities. On the one hand, they almost immediately curtail the flow of imports, are relatively easy to apply, and influence local production within a short time. Decrees concerning tariffs, import prohibitions, and so on are easy for government to impose and — if need be — to change from day to day. Thus, governments may, in principle, fine-tune controls to foreign exchange availabilities, promotional policies for certain industries, world economic conditions, internal crisis, and so on. On the other hand, protectionist measures, which include import controls, have a long-term effect on industrial production and on technological capabilities. The protection they provide, especially when a particular industrial branch is foundering, does not encourage industry to attempt technological improvements or better efficiency and, thus, detracts from the long-term development of industrial or S&T capabilities. Import controls are a double-edged weapon: they can be a powerful stimulus to industrialization in the short term but can lead to a distorted industrial structure and undermine the development of domestic industrial science and technology.

Custom duties and tariffs are usually employed to encourage the import of certain lines of products and discourage the import of others. In most STPI countries, particularly those promoting import substitution, tariffs have been higher for consumer goods than for intermediate inputs and capital goods. The effects, which have been to increase local production of consumer goods, have been

compounded by contextual factors and other policy instruments, and it is unlikely that any alterations in tariffs by themselves will have an impact on the domestic production of machinery and equipment. Although, recently, some countries, such as Brazil and Mexico, have introduced higher tariffs on capital goods, in practice differential custom duties are difficult to apply, and their real impact can be quite different from what was intended. Between the nominal and the effective protection of capital goods industries there are often large discrepancies, as the cases of Mexico and Colombia indicate.

Import permits are a highly flexible and easy-to-apply instrument for import controls. They usually regulate specific categories of imported goods, whereas tariffs are associated with general groups. A large percentage of imports are regulated in this way in the STPI countries. In Korea, an estimated 50% of all imports require permits, and the proportion reaches two-thirds in Mexico and even higher in Perú. Import permits, and their counterpart import prohibitions, are exaggerated custom duties and tariffs, i.e., an import prohibition can be regarded as an infinite tariff.

Foreign exchange quotas are another form of import controls. They depend less on the type of goods being imported than on the availability of foreign exchange. They are a means for allocating foreign exchange to various industrial firms, complementing and even superseding tariffs and import permits. In Perú and, linked to import permits, in Colombia, foreign exchange quotas applied to different industrial branches and to enterprises within these branches have been one of the main policy instruments to control imports.

Because of the multiple influences and the complexities in the application of import controls and particularly because of the interaction between short- and long-term effects, their impact can only be studied properly from an historical perspective. Countries such as Brazil have found it necessary to change their import policies over time and, consequently, to change, and even develop new, policy instruments for import controls, adapting to changing circumstances. In Colombia, a technical study of import controls identified cases both of technological progress and of backwardness that were closely associated with the long-term impact of import controls. In fact, as part of import substitution industrialization policies, import

controls too often ended up as continuous, rather than initial, protection for local industries and turned infant industries into pampered teenagers that were unable to sell their products competitively in the world market. In addition when import controls have protected industries dominated by subsidiaries of multinational corporations, they have introduced substantial social damage.

However, it cannot be argued that protectionist policies put into effect through import controls were, or are, unnecessary; on the contrary, they appear essential for the growth of domestic industry. They should be seen as short-term measures to deal with balance of payments problems, foreign exchange shortages, etc.

Control of Foreign Investment

Like import controls, foreign investment regulations have a multiplicity of objectives, and they also have strong impact on the development of local S&T capabilities. In the STPI countries, where a few foreign-owned firms can, and often do, dominate several industrial branches, investment controls may even have a more direct effect on technological capabilities than do import controls. The industrial branches are comparatively small in the STPI countries, and the technological choices made by the larger — usually foreign-owned — firms have a disproportionately large impact. The impact of foreign investment on the technological profile of industry is, therefore, very large. Furthermore, foreign investment tends to concentrate in the technologically advanced branches of industry (automobiles, domestic appliances, petrochemicals, etc.), whose indirect effects on industry are larger than those of other industrial branches.

To enter certain branches of industry requires very large investments that are beyond the reach of local firms, and even of some governments. This does not imply that foreign firms can provide all the financial resources required, but they are usually able to obtain financing from commercial banks, financing agencies, and international organizations.

Furthermore, foreign firms are often not prepared to set up production facilities or to supply technology except through direct foreign investment that places them in total

control of the operation. For example, some joint ventures in electronics (or petrochemicals) stipulate that a foreign firm will provide the technology in exchange for a certain proportion of the shares.

The issues involved in the control of foreign investment to further technological objectives must be embedded within a larger set of economic and political considerations regarding a country's industrial autonomy. The policy instruments aiming at controlling foreign investment cannot be understood without acknowledging that nationalism plays a most important role in the definition of policies toward direct foreign investment.

In several of the STPI countries, there is a feeling that direct foreign investment undermines not only local private firms but also the nation as a whole, taking resources out of the host nation and diminishing the possibilities of local accumulation and political autonomy.

In fact, all the STPI countries including those, such as South Korea, that are interested in attracting foreign investment, have adopted measures to regulate the activities of foreign investors. The regulations tend to exclude certain industrial branches for foreign investment; restrict the use of local capital by foreign firms; limit foreign control of certain markets; eliminate restrictive business practices; reduce payments abroad for profits, royalties, and technical assistance; eliminate overpricing of intermediate imports and underpricing of exports; and stimulate the effective transfer of skills and know-how.

The possibility of creating and effectively operating these controls in STPI countries depends on the coherence of government policies, the relative weight of foreign investment in industry, and the history and politics behind foreign investment decisions. For example a country with a shortage of foreign exchange and a large foreign debt may liberalize foreign investment policies and relax controls.

The effectiveness of these controls is also affected by administrative capabilities and access to information on foreign firms. At times, a country agrees to foreign investments without adequate knowledge of the characteristics and operation of foreign investors. Furthermore, frequently legislation to control foreign investment contains a number of exceptions, and government agencies and state corporations bend or circumvent the established rules.

In Mexico, foreign capital and its influence have been key political issues for more than 50 years. New legislation approved in 1974 began to systematize the piecemeal decisions taken over time. The law does not revise past investments but concentrates on scrutiny of new ones. To date, it has had little impact, although it is too early to attempt an evaluation. In any case, it provides the government with background information and the means to intervene actively in the regulation of foreign investment.

The Colombian legislation on foreign investment has been related mainly to foreign exchange and fiscal controls, deriving impetus from Decision 24 of the Andean Pact, which established a set of stringent rules for foreign investment. In South Korea, the regulation of foreign investment is mainly aimed at providing a set of stable rules and incentives to stimulate the inflow of foreign capital, although the connection between foreign investment and technology is clearly made and investments are encouraged in areas where technology transfers have been awarded priority. Venezuela, also by virtue of its membership in the Andean Pact, has established foreign investment regulations but has not effectively implemented them because of administrative difficulties, ambiguity in the law, and the lack of strict foreign exchange controls. Recently, technical assistance agreements between the nationalized Venezuelan oil industry and foreign firms appear to contradict some of the pact's provisions on foreign investment and foreign technology control.

The experience of the STPI countries with foreign investment controls is difficult to assess, and the technological implications are even harder to evaluate. Nevertheless, investment controls constitute a source of information and a set of bargaining instruments at the disposal of governments in the STPI countries.

Registries of Licencing Agreements

Another policy instrument to regulate imports is the registry of licencing agreements. It is a mechanism primarily to control imports of know-how, manufacturing procedures and specifications, designs and blueprints, technical assistance, management experience, etc. (disembodied technology). Licencing agreements are contracts by which

technology suppliers sell firms the rights to use their "product."

In the STPI countries, competition among domestic firms is frequently based on their differential access to foreign technology obtained from licencing agreements. Consequently, enterprises are usually eager to sign licencing agreements and often are not cautious about the terms and conditions. Licencers, on their part, have taken advantage of their position and have used the licencing agreements to tie the provision of capital goods and intermediate products, to restrict the sales and marketing operations of the firms, to impose controls on productive activities, and even to set the basis for subsequent takeover of the local firm. There are many instances when intermediate products have been overpriced in licencing agreements.

The registries of licencing agreements in STPI countries were established to control some of the licensors' abuses, focusing initially on cost considerations and trying to reduce the outflow of foreign exchange associated with royalty payments. Their scope was subsequently enlarged to deal with the technology involved and to protect the "national interest."

Registries of licencing agreements first examine the cost of technology imports, particularly because many of the STPI countries have had, and continue to have, balance of payments problems. The examination focuses on the amount of royalty payments and the basis for calculating them, as well as on the pricing of inputs and machinery supplied as part of the agreement. Substantial foreign exchange savings have been reported by the registries' authorities, although the apparent savings may have been transferred out of the country through other channels. Most of the registries insist on the unpackaging of the licencing agreement, separating and identifying payments for patents, technical assistance, information, know-how, and brand names, rather than establishing a global sum. The breakdown is a rather difficult task, but it has contributed to a greater understanding of the process of importing technology. The registries also try to assess the rationale and convenience of the agreement in terms of the "national interest," which is usually defined in rather vague terms. This last criterion is the most difficult to apply, for it requires an understanding of the (frequently ill-defined) long-term development aims of the country,

of the place that domestic S&T capabilities occupy within the perspective, and of the way in which the regulation of technology imports can contribute.

The establishment of registries was opposed by both local and foreign firms operating in STPI countries, as well as by technology suppliers and industrial property lawyers. They all argued that the state had no right to intervene in the bargaining process between suppliers and buyers of technology. Although some firms now realize that the registries enhance their position at the bargaining table, in all the STPI countries, the operation of licencing registries has been fraught with difficult political battles.

There are many difficulties in establishing an appropriate legislative framework for the registries and in devising procedures to guide their operations. In Colombia, Venezuela, Argentina, Mexico, and Perú, the laws set minimum conditions for the approval of licencing agreements, but the agency in charge of the registry develops the detailed rules to be followed during negotiations. These internal rules are as important as the laws, particularly in view of the many gaps in legislation. Needless to say, the administrative and technical capabilities within the registries are also very important and have consistently been one of the main shortcomings of the registries in the STPI countries.

The institutions in charge of the registries range from independent agencies associated with ministries of industry (Mexico), through committees associated with government agencies (Colombia), to technology institutes (until recently, Peru and Argentina), and planning agencies (South Korea). Experience suggests that registries under the auspices of a technology institute (covering industrial research, technical information, norms and standards, and other related functions) review closely the effects of technology imports on the growth of domestic S&T capabilities, whereas registries attached to fiscal and planning agencies pay more attention to financial, foreign exchange, and legal criteria.

The effectiveness of the registries of licencing agreements depends on three conditions. First, support must come from other government bodies, particularly state enterprises. If a registry is marginal to the government's decision-making, it cannot regulate the inflow of disembodied technology. In this regard, administrative coherence among different government

agencies is also important so the registry does not conflict with the aims and actions of other bodies. Second, the registry's own technical and administrative capabilities need to be high, based on highly trained personnel. Too often, as is the case in several STPI countries, registry authorities and personnel do not understand technology transfer; they apply approval criteria inconsistently and create long administrative delays. Finally, a registry must obtain the support and confidence of the local business community, for the formal criteria and rules may be circumvented by covert agreements between technology buyers and suppliers. To function effectively, the registry must show that it is protecting the interests of the local entrepreneurs and can act on their behalf if they submit licencing agreements for approval.

The majority of the registries in the STPI countries have been operating for less than 5 years, and their performance is difficult to evaluate in terms of their impact on the growth of domestic S&T capabilities. One of the most important effects of registries has been to bring into the open the issues associated with technology transfer. In India, especially, the issues have become clear: the amount and basis for calculating royalty payments in different circumstances; the choice of foreign technology suppliers; the continued interest of the technology suppliers in updating and improving their technology; the age of the technology supplied; the question of tied imports of equipment and industrial inputs; the qualifications and expertise of foreign technicians; the proliferation of licencing agreements for similar products; and the connections with the use of local S&T capabilities. Like foreign investment controls, therefore, they have generated a wealth of useful information on technology transfer and have provided an opportunity for government intervention. Now, the question is how best to take advantage of them.

The Patent System

Patents have always had an ambiguous role in less-developed countries. Whereas they were originally given as an encouragement or reward to individual inventors, they are now primarily an instrument of corporate control. In consequence, the property rights inherent

in a patent now defend not the individual but the large corporation. This shift, which began in the U.S. in the early 1900s and was accelerated after World War II, has been accompanied by a world-trade expansion that increased the importance of multicountry patenting.

Patent rights have been the subject of intense debate in STPI countries. The value of the international patent system, with its explicit monopoly rights, has been questioned and considered as a device for maintaining the hegemony of developed countries in industrial production. As a reaction, changes in the patent granting process have been suggested, limiting the time available for protection, expanding compulsory licencing provisions, and restricting product or process coverage. The main idea behind these modifications has been to redefine the patent from an individual to a social right.

The data from STPI countries show consistent trends. The number of patents granted have increased, but both individual and national patent holders account for a decreasing proportion of total patenting. Furthermore, the majority of patents in these countries are held by foreign corporations and are used mainly as devices to impose restrictions on local production of certain goods, thus protecting the market for possible exports from other countries or for eventual production by the patent-holding firms or by a licensee.

The major claim in favour of the patent system, that it encourages invention, has been examined in Mexico. In spite of small numbers of patents in the industrial branches of food processing, capital goods, and petrochemicals, there was little evidence that patents encouraged any inventiveness or industrial creativity. A new patent law, which aims at correcting some of the abuses, has been put into effect in Mexico recently, but it is still too new to assess. In Venezuela, a similar analysis showed little theoretical or empirical evidence to support the most ambitious claims in favour of the international patent system.

From the perspective of regulating technology imports, the patent system is a failure and can be considered a device for foreign patent holders to achieve their objectives in terms of trade flows and productive activities in less-developed countries. Furthermore, there is evidence that patent registration by itself does not constitute a vehicle for the transfer of technology.

Joint Ventures

Joint ventures are an alternative to direct foreign investment and the resultant foreign control over productive activities. They are partnerships between governments and foreign firms and, in some cases, the local private sector to set up productive facilities. The foreign partner is usually sought because of the technology and market it can provide.

In the STPI project, joint ventures involving the petrochemical industry in Brazil and Venezuela were analyzed. In Brazil, they took the form of tripartite firms with participation of foreign firms, local private firms, and the Brazilian government. The state has intervened to exert some control over the operations, thus ensuring that Brazilian industry benefits from joint ventures. However, an initial appraisal of the existing firms suggests that the foreign partners are obtaining a disproportionate share of the benefits — perhaps as the price for the technology — and that joint ventures can improve domestic S&T capabilities if they encourage and employ them.

Unlike Brazil, in Venezuela, the local private sector does not participate in joint ventures, and the state does not intervene appreciably in productive activities. The result is an exaggerated version of the Brazilian case. Although the government has majority ownership in joint ventures, the foreign partner controls the operations and technology. The government lacks the technological expertise to participate in the activities and has not insisted on links with domestic engineering firms and suppliers of capital equipment. At any rate the relative weakness of the firms in these two fields limits their potential contribution.

In other words, unless the local partner, be it the state or private industry, has the capacity to evaluate the technology being supplied and the conditions under which it is supplied, then it acts mainly as a financier in joint ventures and has little influence on their possible impact on local S&T capabilities.

Creating Demand

There is a much more effective means for influencing local S&T capabilities; it is through

the cluster of policy instruments that defines the pattern of demand. Perhaps one of the most important and least understood sources of influence, it consists of all those measures of industrial and government policy that promote an increased demand for S&T, define the areas where S&T knowledge will be required, and decide whether the knowledge will be acquired locally or abroad.

The importance of this cluster of policy instruments lies in the fact that, without a demand for indigenous S&T knowledge, the S&T capabilities developed and protected through other policy instruments remain unused, divorced from production, and impotent in social and economic development. Indeed, it has even been suggested that local S&T capabilities grow only when there is an effective social demand for them. This cluster of policy instruments constitutes the main vehicle for government intervention to promote or stifle such demand.

S&T is Secondary

The reason that this cluster is misunderstood is that none of the policy instruments in it has as its main function the development of local S&T capabilities. At best, S&T development is a secondary objective and at worst, a restriction that must be respected to reach nontechnological aims. The development of S&T capabilities often clashes with other aims such as rapid industrial growth, export promotion, expansion of state enterprises, and so on, producing conflicts that can only be solved through hard political choices.

The policy instruments considered in this cluster — industrial programing, industrial financing, state purchasing power, fiscal measures, price controls, export promotion, and other administrative measures — are closely related to industrialization strategies. The industrialization strategy defines the potential room for maneuver to increase the demand for local S&T knowledge, and the policy instruments determine the extent to which this potential is used. (Some other policy instruments, such as import controls, technical norms and standards, etc., also affect the pattern of demand and should not be disregarded, even though they have been examined elsewhere in this report.)

In the STPI countries, the policy instruments in this cluster have seldom been used

consciously to promote the demand for indigenous S&T knowledge. The industrialization strategies and government policies have paid little attention to local S&T activities, and the policy instruments have been used as a means to respond to short-term pressures without regard to the side effects on the creation and use of domestic S&T capabilities.

Industrial Programing and Priorities

The first policy instrument in this cluster is industrial programing and priority-setting. It consists of the legal, administrative, and institutional measures used by the state to shape the structure of industry and includes incentives, prohibitions, etc.

In the STPI countries, this policy instrument has been mainly passive and not very effective. Nevertheless, its potential is powerful in terms of the changes it can induce in the industrial structure, which conditions the pattern of demand for technology.

Four types of industrial programing are apparent in the STPI countries. The first, which is typical of South Korea's programing mechanisms, is a system of incentives without obligations. It attempts to modify the economic environment of industrial firms and, thus, to exact a particular response, especially in terms of investments. The incentives work when the climate is right; when it's not, they are disregarded. For example, tax incentives are effective tools when firms have few options to offset their tax burden. Their effectiveness can sometimes be increased by behind-the-scenes arm twisting by government, but in general, they are only one element in the large set of market forces that determine investment and, hence, the structure of industry.

The second type of industrial programing is a combination of incentives and state controls, i.e., industrial entrepreneurs who comply with certain requirements are eligible for a series of benefits and incentives. The idea is to restrict the framework within which entrepreneurs can operate and still benefit from the incentives. In practice, this approach, which is exemplified in Mexico's industrial decentralization decree, is limited by the willingness and capability of government agencies to enforce the controls.

The third type of programing instruments consists mainly of compulsory constraints. There may be some incentives associated with the controls, but their relative weight is rather

small in comparison with that of the compulsive measures. The constraints are used by the state to modify the industrial structure in a direct way, without intervention in productive activities. The regulations put into effect in Argentina for the automotive industry are examples as are those contained in Perú's General Law of Industries.

The last type of industrial programing is direct state intervention in productive activities. In this approach, the state reserves certain branches of industry for its own enterprises or joint ventures. There are examples in Peru and in countries such as Brazil and Mexico where the basic industries have been reserved for the state.

None of the STPI countries confines its industrial programing to one approach, but the majority mainly rely on the first two types. In the countries where the other two approaches—compulsory policy instruments and direct government intervention—are apparent, the administrative limitations of government agencies have reduced their impact. In consequence, most STPI countries have had their industrial structures shaped by market forces.

Although industrial programing and priority-setting may be used to promote the growth of local S&T capabilities, they must first have a significant impact on investments and on industrial expansion; have their technological implications clearly spelled out; and have built-in demands for local technology.

Industrial Financing

In practically all STPI countries, the banking system and other financial mechanisms are of great importance for industrial development and could therefore have a strong impact on the development of local S&T capabilities. Given the relative weaknesses of industrial firms in less-developed countries and the difficulties they face in financing their own expansion, they largely resort to financing agencies, particularly state agencies, implying substantial state leverage over industrial firms.

The leverage could be used to influence technological behaviour by establishing certain requirements regarding the choice of technologies, the process of technology imports, and the performance of S&T activities. Special credit lines could be provided for engineering firms, for the

development and testing of new products and technologies, and for research and development activities.

Industrial financing in the STPI countries has been based on banking criteria and technological considerations have seldom been included in the evaluation of loan applications. The notable exceptions are the National Development Bank in Brazil (for example, in 1970 it decided to award loans only to cement firms that were planning to use the dry process in their investment projects) and the Korean state-controlled banks.

The variety of technological criteria that can be introduced into loan evaluation makes industrial finance one of the most powerful policy instruments to promote the demand for local S&T knowledge. To harness the potential power, the state must first control a large proportion of the financial resources available for industry (this is clearly the case in South Korea, Brazil, Mexico, and Perú); second, the state must be able to introduce technological criteria without significantly altering its financing mechanisms. For example, in Perú, technological criteria were incorporated in loan evaluation without altering the procedures. Third, the state should have a clear conception of the direction and ways in which it wishes to channel technological behaviour.

None of these three conditions is too difficult to satisfy in the STPI countries, and particularly in those like Brazil and Mexico that have a long tradition of state participation in industrial financing. But, once again, conflicts may emerge when S&T development objectives imply higher risks, delays, and a possible reduction in growth rates.

State Purchasing Power

Next to industrial programing and to financing, the state's purchasing power can be considered one of the most powerful policy instruments to promote the demand for local S&T activities and knowledge. In most of the STPI countries, state budgets represent a very large proportion of total consumption and investment, and the state is a most important producer, particularly in the basic industries.

As a consequence, governments can establish directives that favour the development of indigenous scientific, technological, and engineering capabilities. For example, when purchasing goods and

services, state enterprises and agencies can give preference to products that incorporate local technology and materials and can continually demand improvements in the quality of goods and services purchased domestically. The state firms or agencies must be willing to incur additional costs, tolerate delays, and accept lower quality standards during the “learning” period so that local suppliers have an opportunity to catch up with their foreign competitors. Unfortunately, the state has seldom been willing, in practice, to risk the time or money to promote local capabilities.

Among the STPI countries, however, there are some positive examples. In Brazil, for instance, large state firms in the basic industries have created a demand for local capital goods, particularly those made to order, and have provided strong impetus for the development of the Brazilian capital goods industry. In Argentina, the experience of the Atomic Energy Commission shows what can be accomplished by a determined and well-planned effort to incorporate local suppliers of equipment, engineering services, and technology: the first atomic power plant of Argentina, built in Atucha, incorporated nearly 50% of local inputs, including the fuel elements. At one time, Argentina had a “Buy Domestic” law, but it was seldom enforced before it was repealed.

Other STPI countries where the state plays a powerful role in the economy, such as South Korea and Perú, have attempted similar policies with limited success.

In contrast, Venezuela, because of the urgency in completing investment programs and because of the risk in local supplies, has invested in massive imports of technology and equipment.

The conflicts associated with policy instruments that have multiple objectives are clear in the case of state enterprises. By virtue of being “enterprises,” they have an accumulation function and are supposed to be profitable; and also, by being part of the “state,” they have a social function and are supposed to further welfare aims. The relative dominance of one or the other role determines the state enterprise’s potential achievement in social objectives, such as development of domestic S&T capabilities. Although the purchasing power of the state is potentially one of the most effective policy instruments for creating a demand for local S&T activities, it must be in the hands of

capable administrators who can make complex choices regarding technological purchases.

Fiscal Measures

In contrast, fiscal measures, no matter how ably administered, are weak policy instruments. Consisting primarily of the tax provisions that affect the economic environment of industrial firms, they usually cut tax burdens of industrial firms, thereby increasing profitability, in exchange for cooperation.

The weakness of these policy instruments results from the fact that they do not affect business performance in a major way. Furthermore, there is usually a multiplicity of tax incentives available, which operate in a redundant and simultaneous way, canceling the potential effect of any single incentive.

Under very special circumstances, however, some fiscal instruments can provide the push for new firms to enter the market and some can even boost the development of local technological capabilities. For instance, in the Colombian textile industry, fiscal rules established the linear depreciation of machinery over 10 years and, coupled with other factors, such as foreign exchange shortages, highly trained personnel, and a vigorous local industry, led to a substantial upgrading of local repair, maintenance, and machinery reconstruction capabilities within textile firms, as well as to a lively second-hand machinery market. However, because of the variety of additional conditions required for fiscal measures to operate as instruments for S&T policy, their potential use to develop S&T capabilities is rather marginal.

Price Controls and Export Promotion

Price controls are seldom, if ever, used as a means to promote the development of S&T capabilities. Yet, through their influence on profitability they can shape the production cost structure and through it influence technological considerations. Price controls that set minimums are usually applied to agricultural products whereas price controls setting upper limits are applied to industrial products. The latter can be used to encourage enterprises to increase cost-reducing activities and operate with greater efficiency.

But the way in which maximums are calculated can profoundly affect their impact on technological decisions. For example, if a percentage markup on total cost (labour and material inputs) is used to define the profit margin and the selling price, then enterprises may be tempted to exaggerate depreciation and amortization charges to increase total costs and, hence, profitability. They would have little incentive to produce at capacity or improve efficiency. On the other hand, if price ceilings are fixed according to a predetermined cost structure and profit margins, there would be a reason for firms to use their capacity.

In the STPI project, price controls were analyzed in several branches of Colombian industry. The findings, although not conclusive, indicated that one of the main options open to industrial entrepreneurs in the face of price controls is to adopt a strategy of technological improvements aimed at optimizing the use of equipment and machinery, thus reducing fixed investment per unit of output, accelerating capital rotation, and increasing profitability.

Price controls need further study, but at present they appear to be a driving force for minor technological improvements.

Most countries with industries eventually encounter limitations in the domestic market for manufactured products and attempt to break their growth bottleneck by encouraging exports. Thus, in the STPI countries, Brazil, Mexico, Colombia, and more recently Perú and Venezuela, have begun to promote exports, whereas Korea has emphasized export promotion since it began to industrialize.

Policy instruments for export promotion aim at providing support and assistance to industries that are likely to penetrate the world market for manufactured products. They give incentives to enterprises that export and also give general support in the form of technical assistance, quality control, market information, and so on. It has been argued, particularly in the Korean and Mexican cases, that export promotion measures cannot be successful unless industry is reasonably efficient. In other words, industry must produce better and cheaper products, even for the home market, to compete advantageously with foreign products and imports.

Policy instruments aimed at promoting exports, therefore, may apply pressures within

industry to increase efficiency, improve quality, and lower prices — all measures that may increase demand for local S&T activities. They may also encourage imports of foreign technologies to please the tastes of consumers in developed countries. Both effects have been identified in the STPI project in different branches of Korean, Brazilian, and Mexican industry, and they point out the complexity of export promotion measures. Like other policy instruments that define the pattern of demand for technology, export promotion is not simple and straightforward, and it requires detailed analyses to unravel the implications for the development of domestic S&T capabilities.

Other Measures

The pattern of demand for technology is also influenced by some administrative actions of the state, such as subsidies and bidding and contracting procedures. A particularly interesting mechanism tried in India has been the creation and support of “ancillary industries” that supply inputs to large public or private corporations. The ancillary industries receive technical and managerial assistance from the “parent” corporations with which they are associated and have a guaranteed market for a proportion of their total output during a certain period.

Many of these ancillary industries employ modern production techniques and, after a short while, become relatively independent. They have been considered as a mechanism to promote enterprise, particularly in engineering. Their impact on the development of local S&T capabilities may be considerable in diffusing S&T knowledge and skills and, as their activities expand and multiply, even creating a demand for S&T services, activities, and personnel. Ancillary enterprises are a means of ensuring that demand is not held captive in large corporations.

Promoting S&T in Enterprises

Another cluster of policy instruments is directed toward inducing industrial firms to perform scientific and technological activities and to absorb technology, whether of foreign or local origin. In the last analysis, it is through improved productivity in enterprises that the

advances in industrial science and technology have an impact on the economy. It is necessary that industrial firms fully assimilate the technology incorporated into their productive activities and be capable of improving on it.

However, when foreign technology is freely available and technology imports dominate the supply, local firms are not likely to invest scarce technical and financial resources in the performance of S&T activities, except routine ones such as quality control, maintenance, etc. In the early stages of industrial development, local firms usually do not place importance on S&T activities; they can enter the market and compete effectively, particularly within a protected environment. The subsidiaries of transnational corporations usually do not engage in S&T activities either, relying on technology transfers from their own headquarters.

As industry develops and competition increases, scientific and technological activities assume more importance. In the STPI countries that have moved into production of capital, intermediate, and basic goods (Argentina, Brazil, India, Mexico, and South Korea), firms have begun to perform in-house S&T activities that go beyond routine tasks. Measures to induce firms to perform S&T activities may be less important when firms are already convinced of the value of in-house S&T.

The countries in the STPI project have not paid much attention to the design and use of policy instruments in this cluster. The two main types that have been employed are special credit lines for scientific and technological activities and tax incentives to encourage firms to do research and development. These two instruments are complemented by administrative measures that facilitate the import of equipment and materials for the performance of in-house R&D by industrial firms. Special credit lines have been offered both in Argentina and Brazil, and tax incentives have been used by Mexico, Perú, and Korea; the administrative facilities were found in India.

Credit Lines

In general, in the STPI countries special credit lines have not been very effective. The Argentine credit lines for prototypes of capital goods and pilot plants were used on few

occasions. Only one loan for pilot plants was granted in 1973-75, and the credit line for prototypes awarded only four loans during the same period. The reasons for this are the general lack of awareness and interest by industrialists (even though it was an industrial association which asked the government to establish the prototypes credit line); the cumbersome and erratic administrative procedures involved; and the lack of active, aggressive attitudes within the agency in charge of administering the loans.

The National Fund for Scientific and Technological Development in Brazil is an omnibus financial instrument, providing funds for universities, research laboratories, and industry. Its main vehicle for channeling funds to industrial enterprises has been the industrial technology development program, which has not accounted for a major share of the resources allocated to the National Fund. At present, the overall impact on industry is uncertain.

Although special credit lines have not had a major impact on the development of internal S&T capabilities within firms, they may perform more effectively if they are designed and operated with a clear understanding of the financial needs of industrial enterprises. New efforts are needed to devise policy instruments that provide risk capital to innovative firms.

Fiscal Incentives

Like special credit lines, fiscal incentives do not appear to have been very effective. The exceptions are the Peruvian 2% fund at ITINTEC and the Korean fund established by the Technology Promotion Law, both of which are compulsory as opposed to "incentives." In Argentina, incentives were established by law and operated for 4 years during which 281 firms submitted more than 3000 applications for tax deductions based on R&D projects. In the end, only 30 projects were approved and deemed worthy of support by the agency in charge of applying the instrument. The majority of the proposals were considered as devices to evade taxes, rather than effective research and development projects. In Mexico, as part of the corporation income tax law, deductions are available for the scientific and technological activities performed by enterprises, but their impact on inducing firms to carry out research and development has

been rather limited because, among other things, the tax authorities do not critically revise the deductions claimed, and the definition of scientific and technological activities is so broad that almost anything can be claimed as a deduction. Korea and India have similar tax incentive provisions, although their effects are also considered uncertain. At present Colombia and Venezuela do not allow tax deductions for research and development expenditures, and in Colombia, a proposal to introduce them was rejected in 1972 as a possible means for tax evasion. Venezuela is planning to set up a fund similar to the ITINTEC fund (in Peru). It will be based on a certain percentage of the gross income of firms, but instead of giving the enterprise the first option to use the funds, it will allow for a wide variety of exonerations.

The ITINTEC system established by the Peruvian government seems to have worked rather well for two reasons: first, the fund is compulsory, although the enterprise may use its contribution (2% of net income before taxes), either to conduct or to contract research; second, industrial research is broadly defined in accordance with the level of development of Peruvian industry. The Korean Technology Promotion Law obliges firms to set aside up to 100% of the amount spent in buying foreign technology or 1% of the value of imported products to do research, either inhouse or under contract with another institution. Like ITINTEC, it had an important impact on the development of industrial technological capabilities and appears to be adequate to the stage of development of industry in the STPI countries. These successful mechanisms require substantive administrative flexibility and a well-trained group of professionals in the government agencies that apply them.

The lack of success of other optional tax incentives suggests that combining tax deductions with compulsory contributions, as is done in both the Peruvian ITINTEC 2% fund and the South Korean fund associated with the Technology Promotion Law, may be more effective in promoting S&T capabilities within industrial enterprises.

Policy Instruments for the Support of S&T Activities

There are policy instruments that support the performance of S&T activities. However,

they do not form a coherent cluster, for the type of support each of the policy instruments provides is quite different.

The policy instruments examined here — technical norms and standards, information centres, personnel training, and consulting and engineering design organizations — are crucial for the development of domestic S&T capabilities. The first policy instrument consists of the organizations, measures, and procedures to define and enforce technical norms and standards for industrial production, and they are closely interrelated with quality control and raising the quality of industrial products. Information centres provide support to the performance of S&T activities and also deal with technological information for industry and extension. They constitute a complex area of study and were examined briefly as part of the STPI project. Personnel training comprises measures that range from on-the-job training to postgraduate education and includes courses at universities, educational institutions, and so on. The scope of personnel training is quite vast, and the STPI project did not focus on it, although a few country teams touched upon it. The last instrument, consulting and engineering design organizations, is one of the links between the production of knowledge, both local and foreign, and its utilization in productive activities. It is very important, and, as a result of the preliminary analysis of STPI, it is the focus of a new project for support by the International Development Research Centre.

Technical Norms, Standards, and Information

Technical norms and standards include standard dimensions, performance characteristics, and quality specifications for manufactured goods. They are a means of introducing uniform quality levels, dimensions and other parameters in products to promote competition and to allow larger scales of production. By standardizing products and intermediate inputs, they introduce competition among the sources of supply and can reduce significantly the inventories necessary to support production.

Technical norms and standards can also help in reducing waste and, if they conform to local manufacturing capabilities, they can promote

industrial development. They constitute a mechanism for the diffusion of technology, because, by definition, they comprise product specifications, testing procedures, and in some cases process specifications. They are also a means to protect the consumers, whose interests are, in principle, taken into consideration when the norms and standards are established.

Although technical norms and standards can become a powerful policy instrument for the development of local S&T capabilities, in the less-developed countries, they are generally translated or copied versions of those used elsewhere, particularly in the industrialized countries. Few efforts have been made to model them to suit local conditions and technological capabilities; therefore, their potential impact on local S&T development is lost.

Norms and standards, when used to promote quality improvements in industrial production, can be made progressively more strict as local industry is capable of complying with them. In this way, firms will upgrade their technological base. If the standards are compulsory (as in food and health products) or associated with policy instruments such as state purchasing, they are especially effective.

Within STPI, several teams examined the system of technical norms and standards in their countries, and most highlighted the difficulties involved in replacing a system of foreign standards because of trade, technology, and investment ties. They pointed out that standards can actually become a barrier to exports, particularly when local industry is not in a position to satisfy them fully.

South Korea, the most export-oriented of the STPI countries, has put great emphasis on designing standards and encouraging industrial enterprises to comply. As a complement to the system of standards, there are regulations on quality control of products to be exported, and several government agencies and trade associations assist firms that export to raise the quality of their products.

South Korea illustrates that technical norms and standards are potentially very powerful instruments to promote the development of local S&T capabilities, but further study is needed to discover ways to capitalize on their potential.

Another means of supporting S&T activities is through information centres, of which there are basically two types. The first, an

autonomous information centre, defines the services to be provided, primarily revolving around the collection, classification, processing, and retrieval of documents and other sources of information. The second, a user-dependent centre, offers services requested and defined by users, particularly industrial firms.

The first type supports research activities and acts as a depository and processor of documents and S&T information. The second is geared toward satisfying the technological information needs of industry.

In STPI, examples of the former are the Brazilian Institute of Bibliography and Documentation and the National Informatics Centre in India. Examples of the latter were identified in Mexico and Korea, although the Mexican centre has adopted a more active stance on dissemination of technical information to industry.

Information centres of both types are necessary for the improvement of technological capabilities in industry and for providing support to the institutions and individuals engaged in the performance of S&T activities. They constitute a policy instrument that cannot be ignored.

Personnel Training

A third policy instrument to support S&T development is personnel training. Rather than being a single instrument that is easy to identify, it consists of measures, organizational arrangements, policies, planning procedures, and so on, that deal with the educational and occupational structure of the labour force. Its importance for S&T development lies in the fact that, in the last analysis, human beings are the key resource for, and the main depositories of, advances in sciences and technology.

The two aspects of personnel training examined in the STPI project were postgraduate education and technical training — the system producing scientists, engineers, and skilled workers. The STPI study is but a taste of the issues involved in the complex interactions between S&T development and personnel training.

South Korea has engaged in an ambitious program to expand the number of qualified scientists and engineers and has emphasized the creation and support of universities. The South Korean Advanced Institute of Science

(KAIS) is a prime example. Devoted to the training of high-level scientists, during the last 7 years, it has showed that it is possible to create graduate centres of excellence within the less-developed countries.

In India, the electronics sector has attempted to work with universities and industry to set guidelines for the preparation of high-level personnel, considering both the quality and content of courses and curricula.

The Peruvian STPI team examined the mining industry, and the metalworking firms providing machinery and equipment to it, to determine the workers' skill requirements. They compared the results with the existing curricula of mining and mechanical engineering schools to identify discrepancies and suggest corrective measures.

Workers' training schemes operate in several STPI countries attempting to upgrade the skill levels of industrial workers. In Mexico, Colombia, Argentina, and Perú, there exist networks of training centres supported in part by the state and in part by private firms through a system of payroll deductions. They suffer from a number of ills, such as high withdrawal rates, the rudimentary literacy level of workers, the low status of skilled and semi-skilled occupations, and the deficiencies in the training systems and methods themselves. In addition, some of the training schemes lack an organic connection with industry that would ensure jobs for the trainees and would translate industrial needs into training schemes.

From the data acquired by the STPI project, little can be said in general about the use of training as a policy instrument; further analysis is clearly needed.

Consulting and Engineering⁹

Consulting and engineering activities in STPI countries have been recognized as a vital component in the development of local S&T capabilities. They can be developed through the use of policy instruments, or they can be considered as policy instruments in themselves. In effect, these organizations can

contribute to more efficient purchases of technology, better use of indigenous R&D results, reduced technical vulnerability, and so on.

The STPI project did not cover the full spectrum of consulting and engineering activities (a new project on this subject was proposed); however, it did highlight a few issues.

A number of policy instruments can be used to stimulate the demand for consulting and engineering services and, if compulsory, they can immediately and directly effect results. In Perú, for example, state financing agencies require that a feasibility study prepared by a local firm be included in investment proposals, substantially increasing demand.

When demand for consulting services is stimulated quickly, however, the supply can become a bottleneck, particularly because the quality of such services may be poor. In other words, measures to increase demand must be accompanied by upgrading the quality of consulting and engineering capabilities.

There are a variety of policy instruments that influence the growth of domestic consulting and engineering, such as the registering of contracts with foreign consultants, fiscal and financial measures to support consulting and engineering firms, measures to restrict the participation of foreign consulting and engineering firms in investment projects, and so on. All were identified in the STPI project as having potential importance, but their impact on the growth of a domestic consulting and engineering capacity, and, hence on S&T development, was uncertain, requiring further study.

Interaction of Policy Instruments and Context

The multiplicity of policy instruments available to promote the development of scientific and technological capabilities constitutes part of the complex picture of S&T policy implementation. The rest of the picture is composed of the context in which policy instruments are used. Science and technology are at the crossroads of many different development objectives, constituting the common ground where the impact of a variety of policies and policy instruments is felt. In addition, science and technology pervade many other development sectors so that it

⁹For a more detailed discussion see Anil Malhotra. *Consulting and Engineering Design Organizations in Developing Countries*. Ottawa, International Development Research Centre.

becomes practically impossible to isolate the development of S&T capabilities and to treat it independently.

Many policies and policy instruments that have other functions as their *raison d'être* have a significant impact on science and technology; for example, the clusters of policy instruments to regulate technology imports and to define the pattern of demand for technology may have positive or negative effects on the development of domestic S&T capabilities. In the STPI countries, to date, the effects have been mostly negative.

There is an apparent need to turn the experience around, and policymakers for S&T development may be tempted to search for total coherence among the policy instruments, orienting all efforts toward enhancing the positive S&T impacts of implicit policy instruments. However, total coherence is a technocratic illusion, for it ignores the real conflicts of interest that emerge within the state, that condition the style of policy implementation, and that influence strongly the design and use of the various policy instruments.

Furthermore, conflicts of interest and their reflection on the state apparatus are not the only influences in the design, performance, and impact of policy instruments, for the context created by historical, social, political, and economic factors is a strong control. In fact, the close interaction between the industrialization strategies, the style of policy implementation, and the clusters of policy instruments indicates that the context frequently overrides the impact of policy instruments.

Government intervention to develop local S&T capabilities will be effective only when action is taken simultaneously to build up an infrastructure for the performance of S&T activities, to regulate technology imports, to define the pattern of demand for S&T knowledge, to promote the performance of S&T activities in enterprises, and to provide support for S&T activities. Although at times contextual factors may have a stronger impact than the policy instruments in a given cluster, their impact cannot be planned or programmed, and trying to anticipate it by failing to act through a particular cluster of instruments would be leaving a key area for policy intervention to uncontrollable forces.

Within each of the clusters, there are certain policy instruments that, because of their nature or their relation to the context

within which they operate, have a stronger impact than others. It is necessary to identify and articulate them so that they may reinforce each other and operate together as a driving force for S&T development.

For example, S&T planning and funding, foreign investment regulations and import controls, industrial financing and state purchasing power, compulsory measures for the performance of S&T activities in enterprises, personnel training, and consulting and engineering services appear to have a stronger impact on S&T development than the other mechanisms in the clusters. Their relative weight in affecting S&T decisions by industrial enterprises, the extent to which other (maybe stronger) objectives prevail over their possible use as S&T policy instruments, the administrative complexity involved in their application, and the opportunity to control and influence their operation with S&T purposes in mind are some of the reasons why.

Tables 1-5 summarize the policy instruments identified by the country teams in the STPI project. The list of policy instruments is by no means exhaustive for each country representing only a subset that was of interest to the STPI teams.

A look at the information and findings from Mexico and Colombia illustrates how policy instruments interact among themselves and with contextual factors. The Mexican case demonstrates how policy instruments can be redundant, attempting one after another to facilitate the operation of industrial firms.¹⁰ For example, any firm in Mexico (up to 49% foreign equity participation) has several options in securing foreign technology. It may seek and obtain credit at preferential interest rates from a state financial institution and then use the credit to acquire one or several machine tools abroad, a procedure permitted by the rules of internal operation of various financial agencies. It may also acquire the machinery by reinvesting profits, deducting the cost from income taxes. If it does the former, it can deduct the corresponding interest from taxable income.

To import the machinery into the country, the firm can obtain a subsidy of 75% of the general import tax. Even without a subsidy, the

¹⁰To place this example in context, see the remarks made on the Mexican industrialization process on page 38 and on the Mexican style of policy implementation, page 60.

Table 1. Infrastructure building in the STPI countries.

Country	Institution Building	S&T Planning	Financing S&T Activities	Other Mechanisms
Argentina	National Institute of Industrial Technology		Permanent national fund for preinvestment studies	
Brazil		Basic Plan for Scientific and Technological Development	S&T Development Plan; S&T fund of the National Development Bank; national fund for scientific and technological development	
Colombia	Industrial Technology Institute	Sectorial plans for S&T development	Research fund of COLCIENCIAS; national budgeting for S&T; national development fund (FONADE)	
Egypt		Plans for research and development		
India	Network of institutions in the electronics industry.	Plan for S&T development		Import facilities for S&T institutes
South Korea	Network of institutions involved in S&T activities; Korean Institute of Science and Technology	Interfacing economic with S&T plans	Funds for S&T through national budget; fund established by the Technology Promotion Law	
Mexico		Plan for S&T development	Special fund for S&T of CONACYT; national fund for preinvestment studies	
Peru	Network of sectorial technological research institutes; Industrial Technology Research Institute (ITINTEC)		Financial mechanism of ITINTEC and other research institutes	
Venezuela		Plan for S&T development	Financing of S&T activities through government budget	

machinery is likely to be subject to low tariffs. Moreover, procedures for calculating taxable income, by allowing greater deductions for fixed investment, favour the acquisition of more sophisticated, labour-saving machinery.

Once the machinery is installed, the company can apply the depreciation coefficients authorized by fiscal legislation for calculating the income tax base. In the case of machine tools, the normal coefficient is 35%,

which permits important deductions during the 1st years of the productive life of a machine: even once the goods have been depreciated from a fiscal point of view, they still have a long productive life ahead and can be easily sold on the secondhand machinery market. The company can then reinstate the process by acquiring new machinery through reinvestment of profits or other sources of financial resources. If the firm must reduce

personnel, the compensation paid to workers is deductible for calculating the income tax base.

The firm can also apply for and obtain a series of fiscal exemptions under the Decree on Decentralization and Industrial Development, which protects machinery imports and offers 50-100% of the general import tax; up to 100% of sales taxes; authorization to depreciate investments in machinery and equipment in accelerated form (coefficients higher than 35%); and other incentives. Moreover, in addition to these federal incentives, the firm can also obtain other incentives from local government agencies.

The company can have access to the exemptions through approval of its "manufacturing program" and can also

arrange for the import of competing products to be subject to the import permits system. The protection thus obtained offers access to the national market under extremely advantageous conditions that may relegate considerations of efficiency and cost reduction to second place.

If the firm is in a position to export, it can negotiate for another preferential credit to finance its sales abroad and can obtain Certificates for Rebate of Indirect Taxes up to 11% of the value of the transaction. These certificates can be used to pay federal taxes that are not earmarked for special purposes.

The firm also receives government subsidies through low prices for services or inputs such as electric energy, water, oil, and basic petrochemical products. If the services

Table 2. Regulating technology imports.

Country	Import Controls	Foreign Investment Controls	Registries of Licencing Agreements	Patent System	Joint Ventures and Technology Transfer
Argentina	Protection of national labour and production law (20.545), decree 751/74	Foreign investment law (20.557), decree 461/73	National registry of technology transfer		
Brazil	Tariffs to regulate imports of goods embodying technology	Foreign capital control laws 4131/72 and 4930/64	Registry of licencing agreements of the National Institute of Industrial Property	National Institute of Industrial Property	State, local, private, and foreign firms (petrochemical sector)
Colombia	Tariffs to regulate imports and affect the choice of equipment	Foreign exchange control law 444/67; regulation of foreign capital, decree 1900/73 (decision 24 of the Andean Pact); division of foreign investment in national planning agency	Regulations on foreign collaboration agreements	Industrial property regime	
India		Foreign investment board for electronics sector			
South Korea	Government mechanisms to regulate foreign trade (import licences, foreign exchange controls, etc.)	Foreign capital inducement law	Technology transfer regulations		

(con't.)

(Table 2 concluded)

Country	Import Controls	Foreign Investment Controls	Registries of Licencing Agreements	Patent System	Joint Ventures and Technology Transfer
Macedonia		Regulation of foreign investment in domestic organization of united labour	Regulations for obtaining industrial property rights		
Mexico	Tariff mechanisms; import permits; public sector import committee	Commission and national registry of foreign investment	National registry of licencing agreements	Industrial property law and the patent system	
Peru	National register of manufactures; import permits; allocation of foreign exchange for imports	Law for the regulation of foreign investment 18900 and 18999 (decision 24 of Andean Pact)	Registry of licencing agreements (ITINTEC)	Industrial property regime	
Venezuela	Tariff mechanisms; import permits	Regulation of foreign investment law (decision 24 of Andean Pact)		Industrial property regime and patent laws	Joint ventures in the petrochemical sector

represent a sizable percentage of the total cost, firms may be motivated toward technologies that save on their use; however, if they are subsidized, there is less incentive to conserve.

The firm can also benefit from other instruments: expenditures on commercial publicity are deductible from taxable income, as are payments for royalties and technical assistance, expenditures for research and experimental development, tests of materials and quality control, management studies, etc., with the result that the base for income tax calculations is considerably reduced. Thus, corporations can benefit from many incentives that the state has designed in the interest of promoting investment and industrialization. Moreover, any firm (up to 49% foreign participation) can benefit from the incentives, regardless of the industrial branch in which it operates.

The cascade of fiscal incentives for Mexican industrial firms means that no single policy instrument will influence decision-making in enterprises. The possible impact from one measure is lost amidst the redundant effect of the other measures. Under such conditions, other sets of policy instruments will have to be

used to influence technological behaviour and will have to be assessed in terms of their interaction with policy instruments of a fiscal and financial nature.

The second example, derived from the Colombian textile and capital goods industries, illustrates how a variety of contextual factors and policy instruments interact with each other and affect the development of S&T capabilities in two different branches of industry.¹¹ The textile industry in Colombia is rather old and well-established with a good entrepreneurial base and a relatively large number of efficient firms. The firms have enjoyed a certain amount of protection for considerable periods but have, nevertheless, become competitive in exports. Tariffs for the import of textile equipment and machinery are very low, but chronic foreign exchange shortages and input controls have limited the importation of capital goods for the textile industry. Furthermore, fiscal requirements have forced the linear

¹¹To place this example in context, see the remarks made on Colombian industrialization on page 38 and on the Colombian style of policy implementation on page 58.

Table 3. Defining the pattern of demand for technology.

Country	Industrial Programing	Industrial Financing Mechanisms	State Purchasing Power
Argentina	Industrial promotion laws (including decentralization); state corporations to promote industrialization (corporations of medium and small enterprises); Reconversion of the Automobile Industry Law	Corporation for the Development of Medium and Small Enterprises	"Buy Domestic" Law
Brazil	Industrial development policies and programs	Special fund for Industrial Financing (FINAME); subsidiaries of the National Development Bank (FIBASE for basic inputs, EMBRAMEC for capital goods; and IBRASA for other sectors); Fund for the Modernization and Reorganization of Industrial Activities; Regional and sectorial financing agencies	State enterprises purchasing local technology
Colombia	Industrial development policies and programs	Credit lines for purchase of local capital goods (IFI); credits for agriculture with impact on industry	
India	Industrial programing for the electronics industry		
South Korea	Set of laws to define industrialization priorities	Array of financial mechanisms for industry	
Mexico	Decentralization of industry manufacturing programs; Law of New and Necessary Industries	National Fund for Industrial Equipment; National Fund for Industrial Promotion; Fund for the Study and Promotion of Industrial Parks and Cities; Fund for the Promotion of Small and Medium Industries	
Peru	General Law of Industries	Development financing corporation; Industrial Development Bank; Mining Development Bank	
Venezuela	Set of laws to define Industrialization priorities	Financial system for industrial development; leasing companies for industry	
Macedonia			

(con't.)

(Table 3 concluded)

Country	Fiscal Measures	Price Controls	Export Promotion Measures	Other Mechanisms
Argentina			Special credit lines for the promotion of exports	
Brazil			Financial mechanism to promote exports (CACEX)	
Colombia	Depreciation coefficient for capital goods; tax deduction for expenses in repairing and reconstructing machinery; fiscal treatment of payments for royalties	Price control mechanisms	Export promotion measures and regulations	
India				Procedures for developing ancillary industries
South Korea	Taxation of industrial enterprises		Export Inspection Law; free export districts	
Mexico	Depreciation of coefficient for fixed assets; fiscal treatment of payments for royalties; taxation of industrial enterprises (income taxes)		Fund for the promotion of exports of manufactured goods	
Peru			Fiscal incentives for export promotion	
Venezuela	Tax and fiscal system for industrial enterprises		Export promotion policies	
Macedonia			Long-term production cooperation agreements	

Table 4. Promoting S&T activities in enterprises.

Country	Special Credit Lines	Tax Incentives	Other Measures
Argentina	Special loans for pilot plants (National Development Bank)		
Brazil	National fund for scientific and technological development (administered by FINEP)	For S&T activities in enterprises	
India		For R&D expenditures	Administrative facilities for S&T activities in enterprises
South Korea	Technological Development Promotion Law; fund created to support S&T activities in industry	For R&D expenditures in industrial enterprises	
Mexico		For R&D expenditures in industrial enterprises	
Peru		ITINTEC system to promote S&T activities in enterprises	

depreciation of machinery and equipment in 10 years and have allowed tax deductions for expenditures in repairs and reconstruction of machinery. Instead of investing in foreign imports, firms have developed highly competent repair and maintenance shops and have participated in a lively secondhand and reconstructed machinery market. They have absorbed imported technology and have even introduced minor innovations and adaptations.

When the government decided to stimulate the growth of an almost nonexistent capital goods industry, it gave tax holidays, preferential fiscal treatment, credit facilities, and other incentives to the firms that moved into the capital goods industries. As a result, large textile firms that had internal repair, maintenance, and reconstruction capabilities profited from turning their workshops into independent machine shops. An incipient capital goods industry emerged for textiles but did not expand to other areas because of the low tariffs for capital goods imports and the lack of credit or other mechanisms to encourage the purchase of local machinery and equipment.

The Colombian experience spotlights some interesting interactions. The two fiscal policy instruments, low depreciation rates and tax deductions for machinery repair and reconstruction, only elicited a positive impact on local S&T capabilities when a contextual

factor, the scarcity of foreign exchange and the consequent limitations in machinery imports, made them relevant. The scarcity of foreign exchange and the import controls associated with it effectively neutralized the low tariffs on imports of capital goods and, combined with policy instruments, stimulated firms to develop their own machinery repair and reconstruction capacity. Furthermore, another contextual factor, the long tradition of the textile industry and its good entrepreneurial and technical base, made it possible for the firms to develop this capacity.

Another set of contextual factors came into play in the textile industry. The fiscal measures put into effect by the government and the scarcity of foreign exchange did not have the same impact on industrial branches where machinery did not play an important role in the productive process (e.g., the pharmaceutical industry) or where it was so specialized that there was little scope for major repair and reconstruction activities (e.g., petrochemicals, automotive). In other words, the contributing factors were the set of policy instruments that operate at the level of the economy, the policy instruments employed by the state at the sectorial level, and the particular technological and economic characteristics of the industrial branch.

The Mexican and Colombian cases both illustrate the dangers involved in making general recommendations on the use of policy

Table 5. Supporting S&T activities.

Country	Technical norms; standards; quality control	Technical Information Systems	Manpower Training	Consulting and Engineering Activities
Argentina	Technical standards; preparation procedures (Argentine Institute for Materials Rationalization)		National Council for Technical Education	Permanent National Fund for Reinvestment Studies; Buy Domestic Law; registry of licencing agreements technical assistance contracts
Brazil		Institute of Bibliography and Documentation	Funds for supporting training activities (FUNTEC and others)	Financing of studies and projects (FINEP)
Colombia	National Council of Technical Standards; Colombian Institute of Technical Standards (ICONTEC)		National Apprenticeship Service	National Fund for Pre-investment Studies (FONADE)
India		National Information Center for the Electronics Industry	Manpower training for the electronics industry	
South Korea	Industrial Standards Law, Korean Standards Research Institute; Korean Standards Association; Quality Control Inspection Law; Weights and Measures Law; Export Inspection Law	Korea Scientific and Technical Information Center (KORSTIC)	Korea Advanced Institute of Science (KAIS); other related institutions; science popularization movement	Engineering Services Promotion Law
Mexico	Technical standards system	Fund for Technical Information for Industry (INFOTEC)	Centers of industrial and technical training	National fund for pre-investment studies
Peru	Technical norms; standards		Educational reform with emphasis on S&T training; National Service of Technical Training for Industry (SENATI)	Development Financing Corporation
Venezuela	Technical norms; quality control			

instruments. The impact of fiscal incentives, of import controls, of financial mechanisms, and of other policy instruments will vary according to the way they interact with each other and with contextual factors. Although the examples have been taken from two specific

policy clusters, the same caveat applies to other policy instruments. Prescriptions on the use and impact of policy instruments must be examined and reinterpreted within context. In fact, there is no substitute for a thorough understanding of the specific local situation.

Chapter 4

Policy Instruments and Technical Change in Industry

Industrial S&T capabilities are the aggregation of capabilities in enterprises, research centres, engineering firms, etc., and cannot be developed if the only perspective taken into account is that of policymakers and government agencies. Policy instruments must also be viewed from the perspective of decision-makers within industrial enterprises.

This exercise requires an analysis of the factors that influence technical decision-making and technical change in industrial branches and enterprises, with the aim of identifying and separating the influence of policy instruments (explicit and implicit) from that of contextual factors (within the economy, industrial branch, and firm). Because of the variety of sources of influence and the lack of well-accepted theories of technical change in the less-developed countries, the task is most difficult.

The methodological guidelines of the STPI project offered an initial conceptualization of technological decisions. The country teams introduced modifications, and the concept was expanded to include technical change and the diffusion of innovations. Technical change is the manifestation of improved S&T capabilities, and conversely, improved S&T capacity in industrial firms, research centres, engineering firms, etc. is a prerequisite to technical change.

The study of technical change and the factors that influence it in several industrial branches was one of the last tasks to be undertaken in the STPI project. Because of time limitations, the diverging views were not contrasted and examined with sufficient depth, and a heterogeneity of approaches and points of view resulted, militating against general conclusions.

Because of their diversity, the STPI studies on technical change in industry do not lend themselves to interpretation according to a rigorous concept of "technical change,"

applied *a posteriori*. Among other things, they differ in their depth of analysis. Those that clearly differentiated the concepts were less descriptive and more analytical than were others.

Levels of Analysis

There were three levels of analysis: the examination of patterns of technical change in an industrial branch, such as the Korean powder metallurgy industry and the Indian electronics industry; the analysis of technological behaviour of enterprises, such as the agricultural implements firms in Colombia and state enterprises in Brazil, focusing on the technological implications and determinants of a firm's decisions; and specific study of the direction and pace of technical change.

Each level involves a higher degree of specificity, concreteness, and insight than the preceding one. They are roughly equivalent to approaches at the branch, enterprise, and plant level, respectively. The second and third levels include both internal industry studies and case studies of state enterprises. Case studies of specific innovations also fall within the third level. Each of the country studies focuses mainly on one level of analysis but usually covers aspects that are relevant to more than one.

In retrospect, it seems the STPI studies on technical change would have benefited from conceptual refinements and clarifications. Most of the studies centred upon external sources of technology, implying that firms' efforts at generating and modifying technology were not systematically investigated; that the analytical framework advanced in some reports was not sufficiently explored in the empirical studies; and that the analyses of policy instruments focused mainly

on investment decisions to establish or expand productive facilities rather than on the use of existing capacity and the S&T activities associated with the operation and gradual improvement of production technology in an enterprise.

In general, S&T policy instruments acted in concert with other factors to influence technical change and the development of S&T capabilities. Their impact is almost impossible to separate from that of the other sources of influence. Nevertheless, in many instances it is possible to identify and appreciate their role in shaping technological decision-making by enterprises and the growth of a domestic S&T capacity and at the same time to obtain valuable insights to guide further research and policymaking.

Toward a Framework for Study

The studies suggest the existence of certain "key paths" or "sequences" that link the sources of influence at the overall or macroeconomic level with technological behaviour at the microeconomic level (within firms). Policy instruments, both implicit and explicit, intervene in the sequences as one of the sources of influence. The sequences produce patterns of technological behaviour in firms; if they remain in existence for some time, they may bring about changes in the technological base of industrial branches or even of other industries.

The recognition, identification, and clear understanding of the sequences is needed to reinforce or offset the effects of contextual factors and implicit policies. At times, there may be little room for flexibility in the design of economic and industrial policies, and a knowledge of the sequences may introduce a certain degree of independence and autonomy in S&T matters, increasing the freedom within overall government policy. S&T policies may even have implicit nontechnological effects, which can be anticipated through study of the sequences. The identification and understanding of the sequences would also reduce uncertainties that plague the design and use of S&T policy instruments.

The policy instruments and the key sequences operate in substantially different ways during periods of economic expansion or recession and are affected by the degree of

economic fluctuations (slight or accentuated), and by the long-term growth rates. Two hypothetical cases, based on conditions found in the STPI countries, illustrate the sway of the economy.

In a country characterized by chronic balance of payments difficulties, a deficit in import capacity, and low long-term rates of economic growth, it could be difficult to increase foreign indebtedness. The most likely economic policy measures would be to devalue the currency in a move to improve relative prices for export goods; to impose restrictions on imports; to raise interest rates to stimulate savings; and to introduce tax measures to postpone investments in plants and equipment.

These measures would have some clear side effects. First, a devaluation increases current import prices and the burden of outstanding debts in foreign currencies. It also reduces domestic wages in comparison with those in foreign countries. The import restrictions, coupled with tax measures designed to discourage investment, reduce the rate of equipment renewals and additions, and the increase in interest rates will make capital more expensive and labour relatively cheaper.

The resulting economic environment will encourage industrial firms to lengthen the average life of their equipment; to take full advantage of their available physical assets; to stretch plant capacity as much as possible and avoid the need for capital investments; and to look for ways of taking better advantage of by-products.

Under different economic circumstances — for instance, where a high rate of growth is expected, investment is promising, and foreign exchange is readily available — the policies and the firms' reactions would vary accordingly. Import restrictions would be lifted, accelerated depreciation regimes would be allowed, access to capital would not be very difficult or costly, and labour would be more expensive because of successful trade union pressures. The firms would likely undertake rapid expansion and investment programs that involve substantial additions to plant and equipment; they would also demand engineering services for the installation of new equipment rather than for improvement of old, and would launch new product lines in view of expanding market prospects.

The side effect of price controls in encouraging unit cost reductions by means of

plant engineering, process optimization, and other in-house S&T activities, is likely to be far greater in the first example than in the second. In the former, the firms would be pressured to undertake cost-reducing programs, whereas in the latter, they would be actively engaged in the introduction of new products that would make it easier to circumvent price controls. Similarly, depreciation rates and tax measures that encourage S&T activities to improve plant utilization, foster repair and maintenance activities, and stimulate the reconstruction of machinery are likely to have a greater impact in the first situation.

The purchasing power of state enterprises is also more influential during economic conditions described in the first example. In the second example, both private and state enterprises are actively engaged in new investment, thus diminishing the relative weight of the state's purchasing power and increasing the competition and risks involved in choosing technology suppliers. As a result, the enterprises are more apt to purchase foreign technology than to invest in domestic S&T capabilities.

On the other hand, policy measures designed to develop local engineering skills are likely to be weaker under the first set of conditions when firms will tend to rely on their own internal S&T skills.

Finally, because of the greater tendency to rely on external S&T inputs during an expansion phase, measures to promote contract research are likely to have a greater impact under the second set of conditions than under the first.

These examples highlight the interplay between macroeconomic conditions, economic and S&T policy instruments, and technological behaviour at the firm level. But there are two additional sets of conditioning factors that must be taken into account when examining the sequences of macro-micro interactions that influence the development of S&T capabilities. The first is the characteristics of the industrial branch, and the second, the characteristics of the firm.

Among the characteristics of industrial branches that require particular attention are whether productive activities are in the hands of a few people or firms, how the branch is structured, how the firms compete, and how sophisticated is the technology associated with the industrial branch. In effect, the impact of macroeconomic circumstances and various policy measures may depend on

whether the firm belongs to a branch of industry where investments in fixed assets are of paramount importance (petrochemicals, fertilizers, steel) or where they are relatively less important (food processing, metal-working); whether price competition plays an important role or is discouraged; whether technology is freely available or controlled by a few technology suppliers; etc. Finally, the characteristics of the enterprise itself—whether it is private, foreign, or state-owned; whether it is large or small; whether it has a good entrepreneurial base or not—also filter and modify the impact of contextual factors and policy instruments.

Therefore, the sequences of macro-micro interactions involve a variety of sources of influence ranging from broad macroeconomic conditions to specific characteristics of the firm, and the impact of policy instruments to foster the development of S&T capabilities has to be examined from the perspective of their place and relative weight within the sequences. Although S&T policies cannot be designed and operated just to influence a particular firm, they can be designed to correspond to a limited number of key sequences. The studies in the STPI project indicate that the sequences and the roles of policy instruments within them are most appropriately studied at the industrial branch level.

STPI Studies on Technical Change

The STPI studies on technical change and S&T development at the branch level were diverse in content and methods (Table 6), although they roughly fall into three categories: industrial-technological studies at the branch level; studies of technological behaviour of enterprises; and specific studies of technical change.

One feature common to the manufacturing branches examined in the industrial-technological studies is the stratified nature of the market, i.e., the coexistence of different sizes and ages of firms, vintages of technology, ownership structure, and so on. The technological behaviour of the firms belonging to different strata is particularly varied, as is the impact of different S&T policy instruments.

Table 6. Selected studies on technical change conducted in the STPI project.

Country	Industrial Technological Studies at the Branch Level	Studies of Technological Behaviour of Enterprises	Specific Studies of Technical Change
Argentina	Machine tools	Case study of SEGBA (state enterprise in charge of electricity generation); Case study of Gas del Estado (state enterprise in charge of gas distribution and marketing)	
Brazil	Machine tools	Case study of ELECTROBRAS (state enterprise in charge of gas distribution and marketing)	Case studies on the diffusion of innovations (textiles, paper, cement industries)
Colombia		Technological behaviour of agricultural implement firms; Technological behaviour of firms in the fertilizers industry	
India	Electronics industry		
Mexico		Case study of impact of transnational corporations on technological development	Orientation of technical change in the capital goods, petrochemical, food industries
South Korea	Powder metallurgy		
Venezuela	Capital goods	Case study of the petrochemical industry	Atypical cases on innovation

In broad terms, the firms serving export markets or the needs of higher income groups tend to be larger, more specialized, and technologically more sophisticated than are the others. They also tend to have greater involvement of foreign capital and to be relatively more efficient in scale of production. In contrast, firms supplying lower quality goods, primarily for the strata of the domestic market with lower income levels, are usually small or intermediate, versatile, and locally owned. They rely on foreign technology inputs to a lesser extent than do their larger counterparts, and they may undertake some routine S&T activities on their own.

An exception is the electronics industry in India: through state intervention and policy measures, small firms have been able to enter and remain in market segments that otherwise would be dominated by large, usually foreign, firms.

In Venezuela, the study on capital goods points out that small firms producing under order may require more sophisticated

technical skills than larger firms engaged in standardized production. It may be inferred, then, that technological constraints do not necessitate large firms — or their attendant market control.

In Colombia, the agricultural implements branch is relatively easy to enter. Firms can be small but still have relatively free access to technology inputs that require only engineering efforts of a simple type. For these reasons, the branch has a low degree of concentration, and firms are largely locally owned. The firms compete mainly on the basis of product innovations (new types of implements) and distribution networks.

In contrast, the fertilizer industry in Colombia is more difficult to enter. It is open mainly to large firms with abundant financial resources, and its technology inputs are largely controlled by equipment suppliers. Thus, the market is highly concentrated, and state and foreign-owned firms play an important role in it. Technological decisions about operations are mainly aimed at cost reductions, demanding repair, maintenance,

and trouble-shooting skills. Furthermore, the focus on cost reductions is sharpened by government price controls and product standards that limit competition in price and product differentiation.

As a matter of fact, there is little price competition in the STPI countries. Competition revolves around controls of distribution channels (e.g., among the larger firms in the Brazilian textile industry); around product design skills (e.g., in the Korean powder metallurgy and the Colombian agricultural implements industries); or around access to know-how (e.g., in the steel and petrochemical industries in STPI countries).

Competition is characterized by heavy reliance on product design skills, financial resources, fairly advanced knowledge of customers' requirements, control over distribution networks, and preferential access to technology. The STPI studies indicate that the patterns are especially prevalent when industrial modernization, often by means of import substitution strategies, is intensified, and progress is achieved in the vertical integration of industry. The studies also indicate that these patterns of competition erect the most effective barriers to entry faced by local small and medium-sized firms, particularly in branches that require stringent process and product specifications and management controls.

Again, only in India are the entry barriers offset. Institutional devices, such as forcing foreign-controlled firms to direct a high proportion of sales to foreign markets, place local and foreign-controlled firms on more equal footing in the domestic market.

All the studies portrayed fairly concentrated and differentiated oligopolies where price competition played a minor role — if any at all. The picture was most exaggerated when it included price controls imposed by the state, ruling out price competition altogether with foreign technology inputs acting as substitutes for innovative skills.

Several studies (machine-tools in Argentina, capital goods in Venezuela, agricultural implements in Colombia) delineated the importance of trade and distribution agents in conveying technical information to firms from capital goods and material input suppliers, as well as from customers. In some instances, the agents even control supplies of technical services such as installation and starting up of equipment, as well as repair, maintenance, and reconditioning services. They also advise

on the choice of techniques, encourage technical updating, and, in general, affect the pace and orientation of the diffusion process in fields, such as metalworking, capital goods, and electronics.

Also, some studies described the demise of traditional artisan skills as the industrialization process advances. Technical skills inherited from the cumulative experience of repair and maintenance shops and acquired through the empirical use of ingenuity in tackling problems played an important role during the first stages of development of domestic industry; however, they were gradually excluded by the increasingly stringent technical requirements posed by foreign-owned or controlled firms; the need to enter and develop export markets; and the internal competitive conditions that emphasize access to foreign technology inputs. The resulting disappearance of skills and culture may be regarded as a social loss but is hardly considered when economic policies are geared to modernizing industry.

Another feature highlighted by the STPI studies is that vertical links — i.e., the way in which a given branch is articulated with the rest of industry — strongly influence the pace and direction of technical change. Most of the studies agreed in this respect, pointing out that the standards demanded by industrial firms, particularly foreign-controlled firms, for their inputs have an important effect on the pace and orientation of technical change in supplying firms. When the industrial customers require high quality, they often hesitate to trust local firms. Only the larger and more technically competent firms, which usually rely on foreign technology inputs, can afford to upgrade their product quality and develop testing and innovative skills.

The size of the market and the demand instabilities also have emerged clearly as affecting, not only the rate of technical improvement, but also the choice of technologies to ensure versatility in plant, machinery, and equipment. When there is a small and erratic demand, firms serve diversified tastes and produce a wide range of products. Firms look for versatile techniques both when making new investments and when adapting existing equipment to functions other than those originally contemplated. The policy instruments — for example, the state's purchasing power — that define the demand for technology are highly relevant in this regard, for they can create incentives for

higher specialization and can help firms to avoid continuous shifts from one line of production to another.

Almost all studies viewed the import substitution industrialization policies as important in generating demand for technology but acknowledged that these policies are seldom used for developing the local S&T capacity. Biases toward balance of payments and other nontechnological objectives, little selectivity, and lack of awareness of the technological consequences have been identified as reasons. In addition, the STPI studies pointed out the lack of relevance of domestic scientific and technological institutions for tackling the technological problems of industry.

State Enterprises

The studies focused separately on technical change in state enterprises, noting that profit maximization is not the only objective of state enterprises. An equally important goal is encouraging and creating better conditions for industrial growth. For this reason, the technological behaviour of state enterprises cannot be explained in terms of the variables applied to private firms. The conflicts that emerge between profit-making and social welfare, as well as the way in which they are resolved, condition to a large extent the possible impact of state enterprises on S&T development. These observations and a few issues associated with them emerge clearly from the STPI studies on the technological behaviour of state enterprises.

Private and state enterprises have at least one thing in common — the market — that markedly affects their technological behaviour, especially the way they articulate with suppliers and consumers. If an enterprise serves an atomized market, it may, within the constraints imposed by government authorities, exert strong pressures to raise the price of its products. On the other hand, if the market is highly concentrated, the buyers enjoy substantial bargaining power. Examples of both situations are found in the Brazilian studies. In power generation, state enterprises are able to impose a policy of differential tariffs (with higher rates for residential consumption), but in flat steel products, state enterprises find it difficult to manipulate prices because of the organization and bargaining power of consumer firms.

The pattern of finance — related, in turn, to pricing policies — has been singled out by all studies as the main determinant in the technological behaviour of state enterprises. The interrelations among finance, pricing policies, and technological behaviour are, however, far from being simple. For example, price controls on state enterprises may endanger their capacity to generate financial resources internally, forcing them to rely upon resource transfers from the government's budget or from foreign sources. Heavy reliance upon budgetary transfers may restrict an enterprise's autonomy, discouraging its plans to enhance its technological capabilities. In contrast, heavy reliance on foreign sources may be incompatible with low profit or unprofitable operations and lead an enterprise to pay attention mainly to short-term performance criteria. Foreign sources of finance often tie the supply of machinery, equipment, and engineering services, leaving little room for the local provision of inputs. To avoid indebtedness, state enterprises sometimes prefer package investment deals with rapid and secure results and engage in restrictive wage and personnel policies.

When a state enterprise relies mainly on self-generated resources to finance its expansion programs, it usually has more room for maneuver in the choice of equipment suppliers. It may increase its purchases of local technological inputs and build up its own S&T capabilities to increase productivity and, hence, its financial resources.

The Argentine, Venezuelan, and South Korean studies on state enterprises showed the underlying, long-term process of learning. They revealed that learning is not exclusively a product of success but can also be produced through failure (although the social costs in failure cannot be ignored). They also showed that the approach taken by state enterprises is substantially altered when undertaking projects that involve sharp discontinuities in the learning process, such as those that require going far beyond routine expansion programs when undertaking new ventures (e.g., the General Cerrito ethane plant by "Gas del Estado" in Argentina). The studies also revealed that technological considerations become secondary when emphasis is placed on fast completion of import substitution projects. Evidence from Venezuela strongly supports this assertion.

Technical Change: the specifics

Some of the STPI studies looked specifically at technical change and the factors that influence it. First, there were studies examining a wide array of innovations concerning processes, products, and materials; second, there were those centring on diffusion of single process innovations; and third, were those examining the main factors that affect technical change in various branches of industry. The first group comprised the Mexican studies on the capital goods, petrochemicals, and food processing industries; the second, the Brazilian studies on textiles, paper, and cement; and the third, the Colombian studies on agricultural implements, fertilizers, and food products.

The Mexican team tried to go beyond the formal categories of "technological decision." They did not focus on a single innovation in the industrial branches because the diffusion of specific innovations was not the matter of concern. Instead, they concentrated on changes in process, product, and materials technology.

They considered cost-reducing changes; product differentiation and diversification; adaptation of production technology to factor endowment; adaptation of production technology to size of market; adaptations to local materials and inputs; and adaptation of product technology to local "consumer preferences." In a sense, the last three types of changes are specific examples of the first two. However, given the importance that technology adaptation has for an economy relying heavily on imports of foreign technology, these technical changes were examined separately.

The teams identified several structural characteristics of the branch that affected technical change:

- Degree of concentration (i.e., volume of production or fixed assets controlled by the top four firms in each branch);
- Foreign investment (presence of multinational firms);
- Distribution by sizes of firms;
- Capital-output, capital-labour, and labour-output ratios;
- Predominant channels of competition (prices, product diversification, cost reduction, marketing, etc.); and
- Size of market and barriers to entry.

Characteristics of the enterprise that appeared to affect technical change included:

- Ownership;
- Size (by number of workers, by fixed assets);
- Regional location; and
- Volume of exports.

The nature of production technology was considered as part of the characteristics of the industrial branches and intimately related to the capital-output and capital-labour ratios. The distinction was made between continuous flow, intermittent (or batch), and discrete processes. Continuous flow, as its name indicates, means that raw materials and other inputs cannot be divided into separate units, distinguishable from one another. Therefore, in order to transport these materials from one reactor or recipient to another, heavier outlays of equipment (tubes and piping, conveyer belts, etc.) are required. The intermittent processes are characterized by the fact that the physico-chemical reactions can take place in containers that can be charged and discharged; outlays may be smaller and there exists more flexibility for the use of labour. Finally, the discrete processes are those in which raw materials, intermediate goods, and final products are distinguishable from one another and can be manipulated separately. Of course, some processes combine two or more features at one stage or another: for example, dairy products like cheese start as a continuous flow process and end as a discrete process with clearly distinguishable units. These characteristics are closely related to scales of production also, since an intermittent process may be feasible at small scales, and continuous flow obviously requires greater scales of production.

During the STPI studies, it was postulated that the processes condition certain technical changes. For example, discrete processes have a higher elasticity of substitution between capital and labour than do continuous flow processes. However, the changes were dictated not only by the technical characteristics of the process but also by the characteristics of the branches and enterprises.

The Mexican studies identified significant process innovations, which were linked to the scale of production within the innovating firm, size of the market served, and demand structure. A constant trend toward higher automation by larger firms was identified in all the lines of capital goods examined: machine-tools, agricultural machinery and implements, and construction machinery. The size of the

market was singled out as the key to product innovations and to changes in the output mix of the firms: the larger the market, the greater the scope for specialization, which is usually rather narrow. Incentives to produce capital goods also appear to have played a role. Output mix flexibility is related to strong cyclical variations in demand vis-a-vis the need to keep certain minimum margins of capacity utilization.

Agricultural machinery producers are an exception to the general trend of output mix diversification, because they have standard product lines that lend themselves more to product adaptation than to changes in product mix. The optional features available may be considered as a means of diversifying the product. The product adaptations in this branch are intended as a non-price competitive device and are stimulated, in part, by price controls.

Efforts to adapt materials and inputs do not appear to have brought about changes in process and product technology. The STPI studies found that changes in the specifications of material inputs were compatible with the initial process and product technologies that had different material inputs specifications. A provisional hypothesis, which was corroborated, was that the use of continuous processes in the petrochemical industry effectively blocked capital-labour substitution.

Analysis of more than 20 policy instruments showed that they seldom affect the main orientations of technical change. The general conclusion was that the dynamics of the branch in which firms are operating and, to a lesser extent, the characteristics of the firms and the type of process being used (although, in fact, this last element can be considered as a characteristic of the branch) are responsible for intensified use of capital and adaptation and diversification of products.

A look at individual policy instruments, however, shows some interesting facts. Although effects may be negligible, at times they may mean significant fiscal sacrifices for the state.¹² Many are unnecessary and irrelevant. For example, the Registry of Transfer of Technology has no relevance to food industries because they are linked to suppliers of technology through the purchase of machinery and equipment, not through

licencing or technical assistance agreements. Patents may have a role to play in some petrochemical processes, less importance in the capital goods industries, and almost no importance to the food industries; however, trademarks play a key role in food industries (where product differentiation is very important) and have no relevance in the petrochemical industries (where product specifications are more important). Trademarks of capital goods may influence a buyer's choice but are not usually as important as product performance.

Depreciation coefficients also have differential effects. The high coefficients allowed for machine tools have encouraged much speculation and have stimulated the imports of capital goods that are later sold in the secondhand machinery market.

Social charges (social security, unemployment benefits, training schemes, etc.) and other instruments normally considered to "increase the cost of labour" (and therefore promote the selection of capital-intensive techniques) were found to increase labour costs by only around 15%. It is difficult to conclude that this increment is responsible for orienting choice of techniques in one direction or another, and, in fact, labour costs were mentioned in a very limited number of cases by the firms that were studied. Clearly, the move toward capital-intensive methods is due to more complex reasons than the simple "rise" in labour costs.

Some fiscal incentives have proved to be unnecessary state sacrifices. For instance, the Decree for Industrial Development and Decentralization, which offers incentives to firms decentralizing their operations, does not have any impact on firms but cuts back the state's revenue. Some firms must locate in highly developed areas near markets or supplies of intermediate inputs (capital goods producers), whereas others must locate in less-developed areas to be close to the sources of raw materials (food processing plants).

Brazil

The studies on technical change conducted by the Brazilian team traced single process innovations embodied in particular pieces of equipment. They distinguished between a firm's choice of techniques and a branch's acceptance of techniques, the latter resulting

¹²See the Mexican case of redundancy of policy instruments page 81.

when a technique has been introduced into a branch and diffused among the firms. The studies showed that diffusion of innovations is associated with market structure and conduct, the characteristics of the firms, and the specific nature of the innovation.

In the textile industry, different behavioural and structural features, such as slow modernization, sparse radical innovations, process discontinuity, diverse degrees of market power associated with locational factors, product differentiation, and ease of entry, led to an accentuated heterogeneity in the industry profile. This contributed to the uneven diffusion of innovations such as the shuttleless loom. In STPI, it was found that the patterns of diffusion are related more to the structural and behavioural characteristics of the textile industry than to the innovation.

The study of the diffusion of special presses in the Brazilian paper industry found that the decision to adopt an innovation was influenced mainly by the technical requirements imposed by the production process. In contrast to the shuttleless loom, the diffusion of the special presses was little affected by market structure and enterprise behavioural traits.

The other study on diffusion concerned that of the dry process in the cement industry. It explained diffusion in terms of the technicalities of the innovation (the extent to which it could actually be introduced) and market structure and behaviour (the firms' propensity to adopt the innovation). Other influential factors were the concentration of technology supply in the hands of one large firm and the Brazilian National Development Bank's decision not to finance expansions of existing plants or new plants that did not use the dry process.

Colombia

The Colombian studies on technical change at the industrial branch level sought to identify the dominant patterns of technological behaviour. They determined whether an enterprise was mainly involved in product diversification to increase its market share or in plant modifications to reduce costs. They also examined behaviour in terms of the significance of the different S&T activities (research and development, reverse engineering, product design,

etc.). The idea was to determine how the various influences condition the impact of policy instruments.

Three categories of factors were found relevant: the technological characteristics of the branch; the structural, mainly economic, characteristics of the branch; and the characteristics of the dominant enterprises. The three categories were considered simultaneously because of the high degree of interaction among them. Taken together, they produce a particular pattern of technological behaviour and decide the possibilities for the development of local S&T capabilities in different branches.

For operational and conceptual reasons, the studies examined the technological characteristics of industrial branches as the starting point. They postulated five ways of incorporating technology into the productive processes: through process and operations specifications; through plant and equipment; through product specifications; through raw materials and inputs; and through personnel. Although all five ways intervene in all productive activities, one of them may play a dominant role in a particular industrial branch. For example, the agricultural implements industry was considered as one where product design and specifications constituted the main channel for incorporating technology into production. The branch was characterized by small and medium-sized enterprises and a high degree of competition. The barriers to entry were not very significant: modest investments were required, access to technology was not restricted (product designs were rather easily copied), and raw materials were readily available. The local market is relatively small, and customers are dispersed, demanding a large variety of products. Thus, marketing and distribution mechanisms play an important role in the branch. The firms compete mainly by diversifying products and adopting new designs. Enterprises are very sensitive to policy instruments related to credit for the commercialization of their products, as well as protective tariffs and measures designed to encourage exports. On the other hand, they show little sensitivity to fiscal policy instruments, price controls, or financial measures.

In the fertilizer industry, technology is incorporated into production mainly through investment in plant and equipment, including

the basic engineering integrated into the plant layout and the technology embodied in machinery and equipment. Fixed assets in the branch require large investments and have a cost structure in which their depreciation and interest payments play an important role. The structure of production in the branch is highly concentrated, and the important barriers to entry are high investments. Access to process know-how and equipment is relatively easy.

Under these conditions, firms compete mainly by reducing their costs; product diversification is almost nonexistent. The firms in this branch are highly sensitive to policy instruments that provide credit for investments in fixed assets and that allow tax exemptions and establish depreciation rates. They are also highly sensitive to price controls. On the other hand, credit mechanisms for product commercialization, the registration of licencing agreements, and export promotion measures are less important.

The Colombian pesticides industry is characterized by the use of imported raw materials and inputs that incorporate technology to a high degree and by the extensive use of licencing agreements. The process specifications are relatively simple as is equipment. Production is not concentrated, even though barriers to entry are very high, reflecting the dependence on inputs protected by patents and secret know-how and the high obsolescence of products. The firms providing raw materials and inputs are few, and the possibilities of vertical integration

for local firms are severely limited. Foreign investment plays a major role.

Under these conditions, the competition strategy of the firms is based on access to licencing agreements and to the import of raw materials and inputs. Financial, fiscal, and export promotion mechanisms have practically no impact on the technological behaviour of firms in the pesticides industry, whereas mechanisms such as the registry of licencing agreements, import controls, and price controls are particularly influential. In general, protectionist measures also have an important impact on the firms in this branch, because they are responsible for creating a local market.

The diversity of approaches to the study of technical change in the STPI countries is an indication that there are several different ways of assessing the impact of policy instruments on technical change and on the development of domestic S&T capabilities. In any event, one conclusion that can be derived from the STPI studies of technical change is that the technological characteristics of the branch, the structure of the branch, and the nature of the dominant firms in each of the branches are major determinants of technical change. Combinations of these three factors need to be investigated within a specific economic, industrial, and S&T context and a given style of government to identify the most effective policy instruments. The research in STPI pointed in some directions that may lead to a better understanding of the phenomena.

Chapter 5

Conclusions and Suggestions for Further Research

There is no adequate way of summarizing the research results obtained in the STPI project. Furthermore, some results are especially difficult to capture and convey through written reports, because they are intangible, coming from the close interaction between researchers and policymakers. There is no way to summarize the many instances where policymakers were influenced by STPI findings or to describe the changing perspectives of researchers as a result of their interaction with policymakers.

It is, however, worthwhile recalling some of the basic premises of the research in STPI. In the first place, the development of indigenous S&T capabilities was considered as an essential condition for achieving a certain degree of autonomy in decision-making on industrial development. The possibility for a country to control its future industrial evolution and to achieve some self-reliance depends increasingly on the capacity to take decisions on technology, to generate technology critical for national development, and to evaluate, absorb, and improve imported technology.¹³

The development of local S&T capabilities in less-developed countries is a long-term proposition. It requires determined efforts on the part of government, anticipating changes in the international situation and contextual factors. A careful appreciation of the international context and its likely evolution is necessary to determine the "room for maneuver" at present and to design policies accordingly. The aim is to take full advantage of the limited opportunities available for the development of domestic S&T capabilities. This requires an appreciation of historical conditions, international relations, the role of science and technology, and the nature and characteristics of the state.

At present, there are several trends that

merit special attention in this regard. Industrialized countries are becoming increasingly reluctant to transfer their technological know-how and to put their S&T capabilities at the disposal of less-developed countries, particularly in those areas where Third World countries may obtain a competitive edge and displace their productive activities. There has been a rising wave of protectionism in the industrialized countries, under the pressure of trade unions, local manufacturers, and politicians. It seeks to curtail the import of certain manufactured goods from less-developed countries because they are perceived as a threat to industry, employment, and the general welfare of industrialized countries. This trend represents a complete change from a few decades ago, when the industrialized countries enjoyed substantial advantages in manufacturing and were the champions of free-trade policies.

Another trend is the increasing differentiation that can be observed among Third World countries, with a few large ones emerging as intermediate industrial powers. It is likely that a new stratification will emerge during the next 30 years and that the least-developed countries will face not only the constraints imposed by the industrialized countries of today but also those imposed by the emerging intermediate powers.

The trends illustrate the importance of taking a long-term view when designing policies and policy instruments to foster the development of domestic S&T capabilities. These are but a few of the relevant issues.

As an action-oriented research project, STPI aimed at reducing the uncertainties in S&T policymaking through improved information. It also attempted a better understanding of the factors that affect the development of science and technology. The experience in the project suggested: first, that the countries must continue to explore new research areas and revise some old ones, primarily because of changing circumstances; second, that more effort must be devoted to understanding the

¹³On this matter see O. Cardettini, ed. *Technological Dependence and Self-reliance in Underdeveloped Countries*. Ottawa, International Development Research Centre.

role of S&T in the development process; and, third, that the type of analysis carried out during the initial phases of the STPI project (covering the nature and characteristics of contextual factors, the role of the state, and a first-cut appreciation of the room for maneuver in S&T development) is essential for adequate policymaking.

In any case, research should be viewed as a permanent process of monitoring the design and impact of policies and policy instruments for S&T development.

Several new research areas emerged directly from the STPI project. Only a few that relate mainly to the S&T policy instruments and their impact will be examined here.

One is the need to explore further the nature of conflicts and contradictions among the various interest groups that struggle for control of the state apparatus. The groups' views on S&T development need to be closely examined to produce a better understanding of the obstacles they impose within a country and, particularly, within the state. Closely related to this is the need to study institutions and organizations involved in the design and implementation of S&T policies, following the general approach advanced in the STPI project.

Second is the need to refine and examine in further depth the concept of "room for maneuver," which determines to a large degree the impact of policy instruments on local S&T capabilities. This involves an appreciation of complex trends in the developed countries, of the changing interactions between industrialized and less-developed countries, and of the evolution of relations among less-developed countries, focusing in each case on the S&T aspects of the networks of trends and interactions. Because of the relatively limited research capacity of individual less-developed countries, this may be a fruitful area for Third World collaboration.

Practically all the specific policy instruments identified and examined in the STPI project require further study and analysis. The knowledge acquired thus far may soon be obsolete, and a few key policy instruments are a priority for research. They are price controls, financial mechanisms, state purchasing power, and fiscal measures, consulting and engineering design organizations, technical norms and standards, and personnel training. Research not only on existing policy instruments but also on the design of new policy instruments is needed to affect the

performance of S&T activities in enterprises. Less research is needed on the policy instruments for building up an S&T infrastructure and for regulating technology imports.

The most intensive research efforts need to be devoted to investigating the impact of policy instruments on technical change and on the development of S&T capabilities. The links between macroeconomic conditions, contextual factors, government policies, and characteristics of industrial branches are the paths and sequences (see page 90) that form technological behaviour and their characterization in different branches is crucial to S&T policy design and implementation. The nature and orientation of technical change in various branches and the differential impact of policy instruments, are two additional aspects that require study. The results obtained in the STPI project have helped in clearing the road for further research efforts and pointing out what remains to be done, particularly in following through and comparing the different approaches adopted by the STPI country teams.

Research is needed to cover a wide area, ranging from a study of the historical conditions producing certain patterns of S&T underdevelopment, to a study testing a theory of technical change in the less-developed economies. It appears necessary to do additional work on the development of a framework that could coherently link the various issues and aspects involved in the development of local S&T capabilities. Designing such a framework is by no means an easy task, but it is much more fruitful than developing partial theories. It would help in putting together the various pieces of knowledge acquired not only in the STPI project but in many other research efforts conducted during the last decade in the field of science, technology, and development.

It is absolutely necessary to de-emphasize industrial technology and focus on agricultural problems, particularly, S&T capabilities for rural development; to examine the S&T characteristics of various social services such as health and education; and to expand studies of the STPI type to other productive activities such as mining, commerce, banking, and so on.

In the last analysis, it is only through a better understanding of the factors and influences that shape the development of science and

technology that the less-developed countries will be able to take control of their own future. The next few decades will see the rise of science and technology as the key determinants of relations between industrialized and Third World countries, and hence it is imperative to learn more about the social conditions that lead to their development. The STPI project was an effort in this direction, and one that aimed at bridging the gap between policymakers and researchers, paying attention to what Francis Bacon postulated 4 centuries ago: *Nam et ipsa scientia potestas est*: "knowledge in itself is the source of power."

References

- Center for Policy Alternatives. 1976. National Support for Science and Technology: an Examination of Foreign Experience. Cambridge, Massachusetts Institute of Technology, vol. 1.
- Chenery, H. 1958. "Políticas y programas de desarrollo," *Boletín Económico de América Latina*, 3(1).
- Myrdal, G. 1968. *Asian Drama*. New York, Pantheon Books, chapter 19 and appendix 8.
- Organization for Economic Co-operation and Development (OECD). 1975. *The Aims and Instruments of Industrial Policy: a Comparative Study*. Paris.
- Pavitt, K. 1974. *Four Country Project: First Draft of the Final Report of the Feasibility Study*. Sussex, Science Policy Research Unit, University of Sussex.
- Sierra, E. 1966. *Análisis e instrumentos de política económica*. Santiago, ILPES, mimeographed notes.
- Tinbergen, J. 1964. *Economic Policy: Principles and Design*. Amsterdam, North Holland Publishing Co.

Appendix I

Institutes and Countries Participating in the STPI Project

Argentina	Secretaría Ejecutiva del Consejo Latinoamericano de Ciencias Sociales (CLACSO) Country Coordinator: Eduardo Amadeo
Brazil	Financiadora de Estudos e Projetos (FINEP) Country Coordinator: Fabio Erber (until September 1974) and José Tavares
Colombia	Fondo Colombiano de Investigaciones Científicas y Proyectos Especiales "Francisco José de Caldas" (COLCIENCIAS) Country Coordinator: Fernando Chaparro
Egypt	Academy of Scientific Research and Technology Country Coordinator: Adel Sabet (until July 1975) and Ahmed Gamal Abdel Samie
India	National Committee on Science and Technology Country Coordinator: Anil Malhotra (until July 1975) and S.K. Subramanian (until March 1976)
South Korea	The Korea Advanced Institute of Science (KAIS) Country Coordinator: KunMo Chung
Mexico	El Colegio de Mexico Country Coordinator: Alejandro Nadal
Peru	Instituto Nacional de Planificación (INP) Country Coordinator: Enrique Estremadoyro (Until February 1975) and Fernando Otero. Technical Directors: Fernando Gonzales Vigil (until February 1975) and Roberto Wangeman
Venezuela	Consejo Nacional de Investigaciones Científicas y Tecnológicas (CONICIT) Country Coordinator: Dulce de Uzategui (until July 1974) and Ignacio Avalos
Yugoslavia (Macedonia)	Faculty of Economics, University of Skopje Country Coordinator: Nikola Kljusev

Appendix II

Chronology of the International Component of the STPI Project

February 1971	Initial idea put forward at a meeting of Latin American science policy organizations in Lima and Cuzco, Perú.
January 1972	Meeting at the Science Policy Research Unit, Sussex University, to discuss project identification report commissioned by IDRC.
August/November 1972	Feasibility studies carried out in Perú and Argentina sponsored by OAS.
January 1973	Project identification meeting convened at Barbados by IDRC. Project proposal prepared by participants.
June 1973	IDRC Board of Governors approves funding of international component and of some country proposals.
June/December 1973	Country teams established.
August 1973	Field coordinator appointed and first meeting of the coordinating committee, Rio de Janeiro, Brazil.
October 1973	Field coordinator's office established in Lima, Perú.
December 1973	IDRC Board of Governors approves funding of the rest of country proposals.
January 1974	Working meeting held in Lima to discuss methods guidelines.
April 1974	Field coordinator's office staff appointed.
May 1974	Second coordinating committee meeting held in Mexico City.
November/December 1974	Third coordinating committee meeting held in Cairo, Egypt.
April 1975	Working meeting on technology transfer held in Ohrid, Macedonia (Yugoslavia).
May 1975	Working meeting on science and technology planning held in Villa de Leyva, Colombia.
July 1975	Fourth coordinating committee meeting held in Seoul, South Korea. Discussion started on procedures for drafting comparative reports.
August 1975	Working meeting on state enterprises and technology policies held in Buenos Aires, Argentina.
November 1975	Working meeting on consulting and engineering design organizations held in Naiguatá, Venezuela.
December 1975	Extension of the international component agreed by IDRC.
January 1976	Fifth coordinating committee meeting held in New Delhi, India. Agenda and procedures for Sussex workshop agreed.
June/July 1976	Sussex workshop held to prepare drafts of main comparative report and review other reports for publication. Editorial Committee appointed.
December 1976	Field coordinator's office closed down. Field research concluded.
January 1977/April 1978	Preparation of STPI comparative reports and meeting of the Editorial Committee to revise the material prepared by the field coordinator.

Appendix III

Organization of the STPI Project and its Evolution

The STPI project was an experiment — a large, self-managed, action-oriented international research project by researchers and policymakers from less-developed countries. The STPI network comprised autonomous country teams, led by country coordinators who were responsible for the project in their country. The coordinating committee, composed of all the country coordinators, was the top authority of the project and was responsible for the conduct of STPI. It met twice a year to monitor and evaluate the progress achieved, as well as to exchange information on the work of each team and the field coordinator's staff.

To ensure continuity and facilitate communication in the STPI network, a field coordinator was appointed to oversee the international component of the project. He was responsible for organizing communication and information flows, for providing methodological assistance to the country teams, and for organizing and preparing the comparative reports. The field coordinator also acted as secretary to the coordinating committee.

At a January 1973 meeting in Barbados, the STPI project proposal was prepared, and the functions of the coordinating committee and of the field coordinator were defined as follows:

Coordinating committee:

- Approves the work of the field coordinator, who is accountable to the committee for all technical matters;
- Identifies the international consultancy studies to be commissioned for the project;
- Sets the time, location, and agenda of its own meetings, and chooses its chairperson;
- Establishes the procedures for preparing the comparative reports in the final phase of the project; and
- Specifies the terms on which additional

funds will be accepted for the international component of the project.

Field coordinator:

- Helps to develop methods guidelines for the country studies and consultancy studies and makes the reports available to the country teams;
- Coordinates the work of the country teams and encourages communication among them;
- Carries out troubleshooting at the request of the teams;
- Organizes the meetings of the coordinating committee;
- Organizes training courses, commissions consultancy studies, and carries out other duties that might be assigned by the coordinating committee within the limitations imposed by the budget for the international component of the project; and
- Prepares a comparative analysis of the project.

The Barbados proposal for the international component of the STPI project was approved by the IDRC governors in June 1973, together with most of the country proposals. The governors agreed that the results and experience obtained in the STPI project should be made available to countries that did not participate in the network and encouraged the dissemination of experiences and results.

The first meeting of the coordinating committee took place in Rio de Janeiro, in August 1973, and the operating procedures and rules by which the project was to be managed were drafted. Discussions were held and decisions made on the chairperson of the committee, the frequency and attendance of meetings, the maximum number of countries in the project, the sources of funds, the relations with other projects, and similar issues. In particular, it was decided that the

field coordinator would be accountable to the coordinating committee in all technical matters, and to the IDRC for administrative matters. Procedures for handling potential conflicts were also devised; it was agreed that the main decisions were to be taken by consensus, and voting procedures were also specified. A distinction was made between working meetings and coordinating committee meetings, restricting the former to technical issues and opening them to any member of a country team. Finally, decisions on training programs and consultancy studies were made, expanding on the initial ideas put forward at Barbados.

The relations with the sponsoring agencies, IDRC and OAS, were also defined at this meeting. The IDRC representative would monitor the progress of the international component through the field coordinator and would establish a similar relationship with the country teams. The OAS liaison officer with STPI would observe the work of the coordinating committee and would oversee the use of OAS funds.

The field coordinator's office was established in Lima in October 1973, and staffing was completed in April 1974, with the arrival of two assistants to the field coordinator. A bimonthly newsletter began in October 1973.

Meetings

The first working meeting took place in Lima in January 1974, where the draft of the first part of the methods guidelines was discussed in detail. Suggestions were made with regard to the contents of the consultancy studies.

The second meeting of the coordinating committee was held in Mexico in May 1974. The revised guidelines were discussed in depth, consultancy studies were examined, and the first draft of the report on technology policies in the People's Republic of China was presented. Approval was given for three other consultancy studies, and there was a discussion of the country progress reports.

Cairo was the location of the third coordinating committee meeting, which took place in November 1974. The problems of communication among country teams were highlighted, the second part of the methods guidelines was discussed, progress reports on consultancy studies were presented, the report of technology policies in post-war

Japan was distributed, and there were discussions on the nature of the research in STPI, the pace of the research, the usefulness of some background studies, the policy on publications, and the first ideas on the evaluation of the organizational structure and of the approach to STPI were put forward. It was agreed that technical discussions of country team reports should be expanded at coordinating committee meetings, and that working meetings should be programed on a variety of topics. A schedule of working meetings on technology transfer, science and technology planning, state enterprises and technology policies, and consulting and engineering organizations was set up.

The next meeting of the STPI network took place in Ohrid, Macedonia, in April 1975. A working meeting, it dealt exclusively with technology transfer. In May 1975 another working meeting took place in Villa de Leyva, Colombia, where the problem of science and technology planning in less-developed countries was discussed.

Seoul, South Korea, was the location of the coordinating committee's fourth meeting, which took place in July 1975. Country team reports and the issue of the final comparative reports were discussed at length. A policy on publications and dissemination of results was agreed upon, two working meetings were planned, decisions on consultancy studies were made, and a general overview of the evolution of STPI was presented and discussed.

Two working level meetings were organized for the second half of 1975. The first took place in Buenos Aires in August and dealt with the role of state enterprises in technology policy. The second was in Naiguatá, Venezuela, and examined the problem of consulting design organizations in less-developed countries.

The fifth and final meeting of the coordinating committee took place in New Delhi in January 1976, where substantive discussions of the teams' research results were held. In particular, the difficulties encountered in examining technological behaviour and technical change at the enterprise level were considered. The general structure of the final comparative reports was discussed at length and an agreement was reached, which defined the framework for the final synthesis workshop to take place in Sussex. Responsibilities were allocated in the preparation of the final comparative reports, an executive editorial committee was created

to review the work of the field coordinator and his staff after the Sussex meeting, and the procedures for the Sussex workshop were defined in detail.

The Sussex workshop was organized in June/July 1976, and the preliminary drafts of many parts of the main comparative report were prepared. Participants at the meeting divided into working groups and reported regularly to plenary sessions. They also took responsibility for tasks, working closely with the field coordinator. The present report and the other technical studies produced by STPI are mostly the result of decisions made and work carried out at the Sussex workshop.

As could be expected in a large and complex undertaking like the STPI project, many difficulties emerged during its lifetime. The problems encountered at the country level, which were varied in nature and complexity, were dealt with for the most part by the country coordinators, although in some cases the field coordinator intervened. A few problems affected the international coordination and the subsequent comparative reports; they will be examined here.

The first problem that emerged was the limited communication among the participating teams, particularly on technical matters. Excluding three or four teams, which remained in close contact with each other and with the field coordinator's office, the flow of information was limited and took place mostly at the coordinating committee meetings. The reasons for this were varied, but there was a structural problem that was not perceived in the project's initial design.

The lack of communication meant that researchers did not benefit from one another's experience. For example, researchers who encountered difficulties in interviewing firms in some industrial branch might have gained from another team that had already encountered the problem. However, by the time a question was formulated and posed to either another team or the field coordinator, and an answer received (generally by mail), it was too late. The researcher who asked the question had already started work without the benefit of the other team's experience. There were many examples where a more flexible and closer interaction among teams would have helped greatly. Two solutions to the communication gap were rejected because they were inconsistent with the STPI approach. One proposal was to slow the pace of the research

to allow for interactions, and the other was to require a highly centralized methodology.

A second problem was that the meetings of the coordinating committee, which all country coordinators were supposed to attend, took place at 6-month intervals. In practice, the participants hardly had enough time to absorb the ideas from one meeting before they were asked to prepare a progress report for the next. This problem was related to the relatively short time available to complete the multiple tasks of the project.

A third problem related to the way in which coordinating committee meetings were conducted. In retrospect, too much time was allocated to discussions on operations, and to the presentation of progress reports, and too little time was devoted to in-depth discussions of empirical results, technical issues, and problems encountered during the research. Although the working meetings offset this problem slightly, they were limited to a single technical issue that usually was not central to the main work of the teams.

The last problem was the uncertain relationship between the country teams and the field coordinator. Exacerbated by the communication problems, difficulties emerged from the multiplicity of roles the field coordinator and his staff were supposed to play. The roles were in conflict at times and required that efforts be spread, perhaps too thinly, among a variety of technical and administrative functions. The fact that the field coordinator was not engaged in empirical research limited his ability to answer specific technical queries, although his involvement with an institution dealing with industrial technology policy helped him to maintain a sensitivity to the requirements of policymakers.

The relationship between the country coordinators and the field coordinator went through three distinct phases. In the first, the field coordinator provided the country teams with organizational and methodological support, helping the coordinators to establish their teams and launch their research efforts. The second phase saw the field coordinator and the country teams working more or less independently, the former on the organization and supervision of the consultancy and background reports and the latter on the conduct of the research in their own countries. In the third phase, the field coordinator prepared the comparative report, using the inputs provided by the teams. The

first phase went approximately from the beginning of the project (August 1973) until the Mexico meeting of the coordinating committee (May 1974); the second phase from that meeting to the Seoul meeting of the coordinating committee (July 1975); and the third from then to the end of the project in December 1976.

Finally, there were several delays in the project. Although the timetable called for all the country work to be completed by February 1976 and the comparative analysis by August 1976, the complexity of the research tasks and the organizational difficulties encountered by some teams made it impossible to meet the deadlines. The project was extended, and the teams were asked to present their results at least by June/July 1976.

Most of the teams did so, although a few delivered their reports to the field coordinator's office after the Sussex meeting. Consequently, the inputs to the international comparative reports vary considerably in content and degree of completion.

The setup for the conduct of comparative action-oriented research succeeded in keeping the STPI network together and in providing a forum for the exchange of points of view and results. It also allowed for the preparation of several reports on subjects that had not previously been researched. It created a learning environment for the participants who were highly motivated and took advantage of the opportunities offered by the unique structure of STPI's autonomous teams and international coordination.

Appendix IV

Survey of the Country Teams' Work

The organization, composition, and orientation of each of the country teams reflected their own interests and those of the institutions that hosted them, always within the framework of the STPI project concerns. A brief review of the approach and the work of each team may help to place the STPI project and the comparative reports in perspective. To complete the survey, a description of the field coordinator's office work is given.

Argentina: The initial location for the Argentine team was the Department of Economics of the Catholic University. However, after some months, the university decided to withdraw its application and the country coordinator moved to the Argentine branch of the executive secretariat of the Latin American Social Science Council (CLACSO). The team was headed by Eduardo Amadeo, an economist, and two other members were appointed to work full time on the project. An advisory committee of several researchers and policymakers active in science and technology policy was formed. To carry out the research, the team relied on consultants who wrote reports on specific subjects that were integrated into a final report.

A significant change took place when the country coordinator was named president of the Instituto Nacional de Tecnología Industrial (INTI), the national industrial technology institute, which is the largest and most

important industrial research organization in Argentina. Mr. Amadeo never relinquished his formal role as coordinator; after 6 months, he left his new post and resumed his position as country coordinator. Because most of the work was well under way, his absence did not substantially alter the team's pace, although the preparation of the Argentine synthesis report was postponed. Part of the team's work was reoriented to be most useful to the coordinator in his new position.

The Argentines focused on two branches of industry — machine tools and petrochemicals — but studied many broader issues. For instance, the reports include a document on the technological content of the 3-year development plan (1974-77), a study of the Argentine industrial structure, a description and brief analysis of technology policy instruments in Argentina, a study of the system for regulating technology imports, and several short reports on international technical assistance as an instrument of technology policy.

The structure of the Argentine scientific and technological system was studied in detail, as were the conditions under which it could be made more responsive to industry's needs. The Argentines covered the public sector, examining the possible role of the public sector as promoter of scientific and technological development. Detailed studies

were carried out at two enterprises; one in charge of generating electricity in Buenos Aires (SEGBA) and the other in charge of generating and distributing gas for household and industrial consumption. Other contributions of the Argentine team were a study of the emergence and development of engineering and consulting firms in the chemical process industries, a detailed analysis of two research centres within the national industrial technology institute (INTI), and two short papers on capital accumulation and on the crisis of capitalism.

The Argentine team followed the methods guidelines; however, they produced a series of thematic reports on issues of actual and potential interest to policymakers in the country, coinciding with the themes selected for study in STPI.

Brazil: The Brazilian team was hosted at the research group of the Financiadora de Estudos e Projetos (FINEP), the state agency in charge of financing studies for investment projects and also the executive arm of the national fund for scientific and technological development. The first coordinator was the director of the research group, Fabio Erber. When he took a leave of absence from FINEP in September 1974, he was replaced by José Tavares, the new head of the research group. The group at FINEP had been carrying out research on science and technology policy for some time, and the STPI assignment was one of its tasks for 1973-76. Practically all of the work was done by members of the FINEP research group, although two or three reports were contracted to professionals outside FINEP.

From the beginning, the Brazilians decided to concentrate on the role of state enterprises in technology policy. They chose branches of industry that were dominated by state enterprises (oil and petrochemicals, steel, and electricity), conducting detailed interviews, analyzing existing data, and testing hypotheses systematically to cover issues such as the selection of equipment and processes, the purchase of engineering services, the performance of research and development, and the planning activities at these state enterprises.

In addition to the new material generated by the Brazilian team during STPI, several reports based on past research carried out by FINEP were made available to the STPI network. These included background reports on the organization and structure of the Brazilian science and technology system, a

study on the machine tool industry, a report on the demand for services of 12 research institutes, and a background report on industrial policies in Brazil during the last 2 decades.

In parallel with the work for STPI, the FINEP team was also engaged in a research project on the diffusion of technical innovations in three industrial branches (pulp and paper, cement, and textiles) and they agreed to put their results at the disposal of the STPI network as an additional contribution.

The Brazilian team used the guidelines only as a general reference, given that most of their work went along different lines from those originally envisaged for the project. Nevertheless, the richness and variety of their material effectively upgraded the comparative reports.

Colombia: No Colombian participant was present at the Barbados meeting, and the Colombian application to join the STPI network was received later and formally accepted at the Rio meeting of the coordinating committee. The team was hosted by the Colombian Council for Science and Technology, COLCIENCIAS, and was headed by a sociologist, Fernando Chaparro. In spite of joining the STPI network late, the Colombian team caught up with the pace of work and finished all its work by the deadline.

COLCIENCIAS organized a special team with five members who devoted practically all their time to research in STPI. Several other consultants were also asked to prepare reports on issues of specific interest such as selected policy instruments. For example, a study was commissioned on the impact of tariff mechanisms; a report was prepared on the influence of price controls; and a preliminary analysis of the possible use of the state's purchasing power as an instrument of technology policy was also prepared. The branches chosen for study were all linked to agriculture: fertilizers and pesticides, agricultural machinery, and food processing, taking into consideration the interests of Colombian policymakers as perceived by the team. In these branch studies, the methods guidelines were closely followed.

Other reports prepared by the Colombian team include a study of science and technology planning, an analysis of implicit industrial technology policies, a conceptual framework for the study of consulting and engineering organizations, a series of reports on industrial branches based on discussions

with panels of experts, a study of science and technology policies in the agricultural sector (to complement the analysis done for industry), and two essays on the process of industrialization in Colombia and its technological implications.

Five groups of policy instruments were studied in detail, and their impact on each branch was examined through interviews at various enterprises. All of the findings were integrated into the final report of the Colombian team.

Egypt: Although an Egyptian representative participated in the initial deliberations leading to the STPI project, it was not possible to organize the team to carry out research and prepare inputs for the international comparison. There were several administrative difficulties and staffing problems that prevented the organization of a working team. The host institution was the Academy of Scientific Research and Technology and the first coordinator was Adel Sabet, who was replaced by Gamal A. Samie in July 1975. The Egyptian team presented papers that were personal contributions based on past experience rather than the result of research carried out by a team; and research was not begun at the academy until the second half of 1976.

India: The host organization in India was the National Committee on Science and Technology, and the first coordinator was Anil Malhotra, who was replaced in June 1975 by S.K. Subramanian. Mr Subramanian resigned in March 1976, and no one replaced him. No funds were requested to set up a country team in India, and the Indians provided background material that had already been collected as background for a new science and technology plan.

Three background documents were distributed along with the final S&T plan to all the teams in STPI. In addition, a report on foreign collaboration, a note on science and technology planning in India, a survey of engineering consultancy services, a report on the development of the electronics industry, and two papers on small-scale industries and technology transfer were distributed by the Indian coordinator. No empirical research was done following the methods guidelines, and the Indian contribution to the comparative reports reflects this.

South Korea: The South Korean team was one of the first to be organized and was established at the Korean Advanced Institute of Science,

KAIS, as part of the activities of its science, technology, and society program. KunMo Chung was named country coordinator and the team consisted of five other members. All but one of them had other academic duties and could allocate only a portion of their time to STPI research. Then, Graham Jones was hired to advise in the preparation of the report for phase 1.

The South Korean team advanced rapidly and completed its work in time for the Sussex workshop, following the methods guidelines and introducing modifications only where necessary. Two reports were produced corresponding to the requirements for phases 1 and 2 of the project.

The branches chosen for study were electronics, petrochemicals, and powder metallurgy, and a report was prepared for each one. In addition, the team prepared documents on engineering services and industrialization in South Korea, on the Korean Institute of Science and Technology, on transfer of technology in the electronics industry, on the interface between the science and technology plan and the economic development plan, and on state enterprises in technical development.

Although most of the work was done by the team located at KAIS, consultants were asked to deal with specifics. The team predominantly represented engineering and physical sciences, but an economist who was a senior government official, helped to relate the results to South Korean policymakers and to balance the other team members' biases.

Mexico: The Mexican team was among the first to start working in STPI and was located at El Colegio de Mexico, an academic and social research and graduate training organization. Alejandro Nadal was country coordinator and there were four other members of the team who worked full time on STPI. The Mexican team initially followed the guidelines rather closely and was one of the first in suggesting modifications and changes as a result of contrasting concepts with preliminary research findings. In particular, the team found it difficult to interpret the results of interviews in enterprises using the schema proposed to study technological behaviour. The branches chosen for detailed study were capital goods, food processing, and petrochemicals.

A background report on the structure and evolution of the Mexican scientific and technological system was prepared, together

with a description of the industrialization process and of agricultural development. Documents on particular subjects included a report on engineering firms, a study of the technology policy of PEMEX (the state oil monopoly), and progress reports dealing with hypotheses on the impact of policy instruments on technical behaviour at the enterprise level, a description of policy instruments in Mexico, etc.

Most of the findings of the Mexican team were integrated into the main final report, part of which was delivered at the coordinating committee meeting in New Delhi (January 1976) and the rest at the Sussex workshop (June 1976). The work of the Mexican team covered practically all the research topics considered in STPI, and its contribution to the comparative report reflects this. The Mexican report was published in Spanish in 1977 and was awarded second prize in a contest for the best works in economics.

For various reasons, the Mexican team chose to limit its direct interaction with policymakers and followed its own research program. Results were made available to policymakers in the form of draft reports, and through the participation of the coordinator in one of the committees established to prepare the Mexican plan for science and technology.

Peru: The Peruvian team was established within the research group of the National Planning Institute. A series of administrative difficulties affected the progress of the team, including a change of technical director, when Fernando Gonzales Vigil was replaced by Roberto Wangeman in February 1975. Approximately two-thirds of the research was completed in time for the Sussex workshop.

From the beginning, the team decided to adopt a sectorial approach to the research. Efforts were focused on the study of industrial branches connected with the extraction and processing of minerals and with the provision of machinery for the mining industry. The steel industry was also studied, with emphasis on the state enterprise in charge of the largest steelworks. This meant that the guidelines were used primarily in sectorial studies and in the analysis of policy instruments.

Background reports on the situation of the scientific and technological system and on the evolution of Peruvian industry were prepared following the general framework put forward in the guidelines. In addition to these and the sectorial reports, the team prepared other

documents, dealing with issues such as explicit and implicit science and technology policies, consulting and engineering capabilities, the possible use of state enterprises as instruments of technology policy, and the government administrative machinery for science and technology policy.

The Peruvian team was located within an official government organization, but its direct impact on policymaking is difficult to assess because it took the form of daily contact with government officials. On the basis of the sectorial reports on mining, a committee has been set up to review the findings of the STPI team.

Venezuela: The Venezuelan team was hosted by the national council of science and technology (CONICIT) and was among the first to start working. The team was initially dominated by sociologists, although economists increased their participation at later stages. The first coordinator, Dulce de Uzcátegui, was replaced by Luis Matos, who was soon followed by Ignacio Avalos. Three other members worked full time, and the team was biased toward sociology and economics.

They progressed through two stages punctuated by a change in government. In the first stage, most of the background reports corresponding to phases 1 and 2 of the STPI methods were prepared, covering the science and technology, the political, the educational, and the economic systems. These reports were made obsolete by the change in government. In the second stage, the team tried to adjust to the new situation, repeating some of the earlier studies and continuing the research. However, the organization of a national congress on science and technology, which mobilized all the staff working at CONICIT, affected the team's progress.

The branches chosen for study were capital goods, electronics, and petrochemicals. In addition, reports were written on specific issues such as the government organizational structure for science and technology policy, instruments for industrial science and technology policy, economic and financial policy instruments and their impact on technology, the purchase of capital goods in two industrial branches, and the relations between the financial system and technology policy. The Venezuelan team concluded its research shortly after the Sussex workshop.

The fact that the Venezuelan team was located in a government agency that took a very active role in science and technology

policy after the change in government created both opportunities and problems. As a result of the new tasks undertaken by CONICIT, the pace and continuity of the STPI work was frequently altered. On the other hand, there was more possibility for actively contributing to policymaking. The Venezuelan contribution to the comparative reports reflects this situation.

Yugoslavia (Macedonia): The Macedonian team was organized at the faculty of economics of the University of Skopje. A senior faculty member, Nikola Kljusev, was appointed coordinator. The team was composed of a very large number of faculty members and researchers who devoted part of their time to STPI. The tasks were subdivided and individual reports requested from various members of the team, although at a later stage two team members were asked to work full time on STPI.

The Macedonian team did not follow the guidelines, except in the preparation of a background report for phase 1. Individual reports were submitted on issues of interest to the STPI network, covering topics such as the problems of research and development in industrial enterprises, aspects of science and technology policy in Yugoslavia, the metallurgical industry in Macedonia, and the growth of engineering firms in Yugoslavia.

The Macedonian team's specificity is reflected in their relatively limited contribution to the comparative reports. At any rate, given the high degree of participation of professionals at all levels in policymaking in the Yugoslav self-managed economy, it is rather difficult to assess their contribution toward policymaking in conventional terms.

The Field Coordinator's Office: In August 1973, at the first meeting of the coordinating committee, Francisco Sagasti was appointed field coordinator of the project and his office was established shortly thereafter and began operating in a limited way. Staffing was com-

pleted in April 1974 with the addition of two members.

The field coordinator's office was independent from the teams and was not engaged directly in empirical research. It offered organizational and technical support and contracted consultants to prepare reports on topics defined by the coordinating committee.

The field coordinator, first, drew up methods guidelines for phases 1 and 2 of the project. Background reports on technology policy in China, on technological dependence/self-reliance, on science and technology planning, on technology policies in Japan, and on technology transfer were also prepared, either by staff members of the field coordinator's office or by consultants. The guidelines for phases 3 and 4 of the project were prepared jointly by the field coordinator and a consultant. The office also organized the Sussex workshop and drafted the comparative reports. The field coordinator was also active in the board of the Peruvian Industrial Technology Institute (ITINTEC).

With the exception of the teams that were engaged in science and technology policy research as part of the activities of their institutions (the Brazilian and South Korean teams, for example), the teams were dismantled after the STPI project was completed. The field coordinator's office was closed in December 1976, and the comparative reports were prepared during 1977/1978, although some teams had not finished their work by April 1978. Even though most teams had concluded their STPI activities by the end of 1977, this does not mean that the team members left the field of S&T policy research and that their effort in STPI was not followed up. What was dismantled, as planned from the beginning, was the formal structure of the STPI project. The network of personal contacts remains in operation and most of the former team members are active in the field of science and technology policy, carrying the experience accumulated in STPI to their new positions.

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